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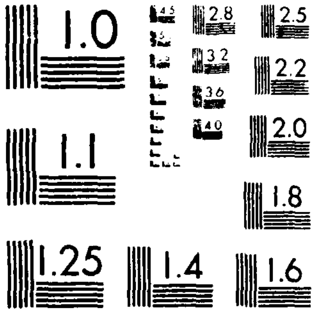

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THESIS

RUSSIAN CULTURE AND SOVIET SCIENCE

by

Beulah Clare Galvin

March 1984

Thesis Advisor: S. Jurika, Jr.

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This thesis analyzes the effect of Russian culture and Soviet ideology on Soviet science. Russian culture is shown to inhibit the ability of Soviet scientists to achieve major breakthroughs or develop radically new theories. Culture does, however, enhance the Soviet ability to thoroughly exploit and innovatively apply proven scientific theories and technologies. The Soviet inability to achieve

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Russian Culture and Soviet Science

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis analyzes the effect of Russian culture and Soviet ideology on Soviet science. Russian culture is shown to inhibit the ability of Soviet scientists to achieve major breakthroughs or develop radically new theories. Culture does, however, enhance the Soviet ability to thoroughly exploit and innovatively apply proven scientific theories and technologies. The Soviet inability to achieve breakthroughs compels their reliance on Western technology. Their proficiency in exploiting proven technologies enables the Soviets to compete effectively with Western military systems. Thomas Kuhn's description of the scientific process is utilized as a framework in this analysis.

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AN SSR	USSR Academy of Sciences
GKNT	State Committee for Science and Technology
GOSBANK	State Bank
GOSKOMIZOBRETENIYA	State Committee for Inventions and Discoveries
GOSPLAN	State Planning Committee
GOSSNAB	State Committee for Material and Technical Supply
GOSSTANDART	State Committee for Standards
GOSSTROY	State Committee for Construction Affairs
KGB	Committee for State Security
MinVUZ	Ministry of Higher and Specialized Education
MPA	Main Political Administration of the Soviet Army and Navy
VINITI	All-Union Institute of Scientific and Technical Information
VNTIT	All-Union Scientific and Technical Information Center
VPK	Military-Industrial Commission
VUZy	non-university higher educational institutes

I. INTRODUCTION

The ability of a nation to pursue scientific research is one of the many factors determining its national security. Although distinct from technology, since the 1870s scientific research has become increasingly related to technological advances and increasingly relevant to socioeconomic developments. Before then, technological improvements had been generated primarily by craftsmen and innovat : independently of the achievements of the scienti - community [Ref. 1: pp. 142-146]. Since the 187(however, the pattern of technological development has been typified by increased interaction between the basic research, applied research, and engineering communities. Basic scientific research has thus assumed an integral role in determining national economic and military capabilities through technological advances.

The importance of science to a nation's security was highlighted in the report submitted by the United States National Commission on Excellence in Education to President Reagan in April, 1983. This report, "A Nation at Risk: The Imperative for Educational Reform", while addressing the overall deterioration in American precollege education, identifies science and mathematics as critical areas to be

emphasized in educational reform. Glenn T. Seaborg, a member of the Commission, writes that

> The deficiency in the quality and quantity of teaching of science and mathematics--subjects that are emphasized in a number of countries that are our competitors--is undoubtedly a factor in our country's economic decline. Lack of scientific literacy threatens the efficient, or even adequate, functioning of our democracy in this scientific age. [Ref. 2: p. 219]

Of particular importance to the United States and the Union of Soviet Socialist Republics is the role of science in the military sphere. As intense military competitors, the two nations are concerned not only with acquiring and maintaining an optimal technological edge vis a vis each other but also are the world leaders and providers of military technology. For the United States, maintaining a technological superiority has been an essential element in its strategy to counter the Soviet ability to maintain massive troop levels and sustain the production of commensurate quantities of military equipment.

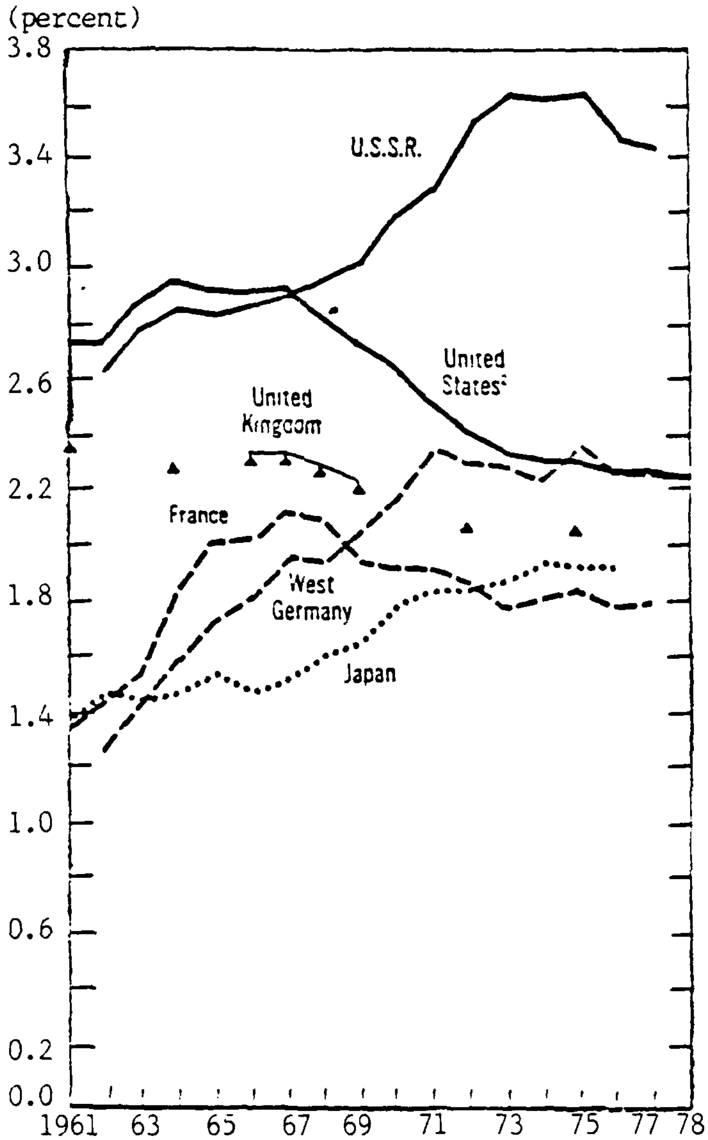
By directly identifying the threat and recognizing the "natural vulnerabilities" [Ref. 3: p. 70] and limitations of a democratic state when confronted over an extended period by a totalitarian state, NSC 68 began the evolution of a policy which relies on a system of alliances and on technological superiority to offset resource constraints. Historically, this technological reliance was initially based on the United States' sole possession of an atomic

capability during the late 1940s. In the 1950s, as the Soviets progressed in their ability to produce and deliver nuclear weapons, the United States relied upon its superior strategic airpower and tactical nuclear capability. Even as Soviet military technology continued to close the gap in strategic weapons over the next two decades, the United States and its allies pursued a "doctrine of quality" [Ref. 4: p. 550], emphasizing qualitative rather than numerical superiority in conventional forces. Most recently, the American penchant for relying on technological developments was demonstrated in President Reagan's dramatic "Star Wars" speech of March 23, 1983 in which he announced the intention to increase research and development efforts in spaceborne antiballistic missile systems. Thus, since the initial stages of the United States-Soviet confrontation, the United States depended on technological superiority to counter Soviet quantitative superiority. This technological superiority is, in turn, partially dependent on American resourcefulness in scientific research.

For the Soviet Union, scientific and technical advances were essential to overcoming the American threat of nuclear blackmail. Having achieved a rough degree of strategic parity, however, the Soviet Union continued to invest heavily in research and development. This investment in

dollar amounts for the period 1964 to 1968 was approximately half that of the United States. By 1970, however, the Soviet investment in research and development was equal to that of the United States. Since 1970 the dollar cost of Soviet research, development, test and evaluation has been growing at approximately seven percent a year, bringing the 1976 cost to 50 percent over the comparable United States investment [Ref. 4: p. 558; and Ref. 5: p. 29]. Significantly, since 1976 the Soviets have been increasing the percentage of research, development, test and evaluation expenditures relative to their total military budget. The emphasis placed by the Soviet Union on research and development, in comparison with the United States and other countries, can be seen in Figure 1 which illustrates the percent of gross national product each country devoted to research and development for the period 1961 to 1978. [Ref. 6: p. 6]

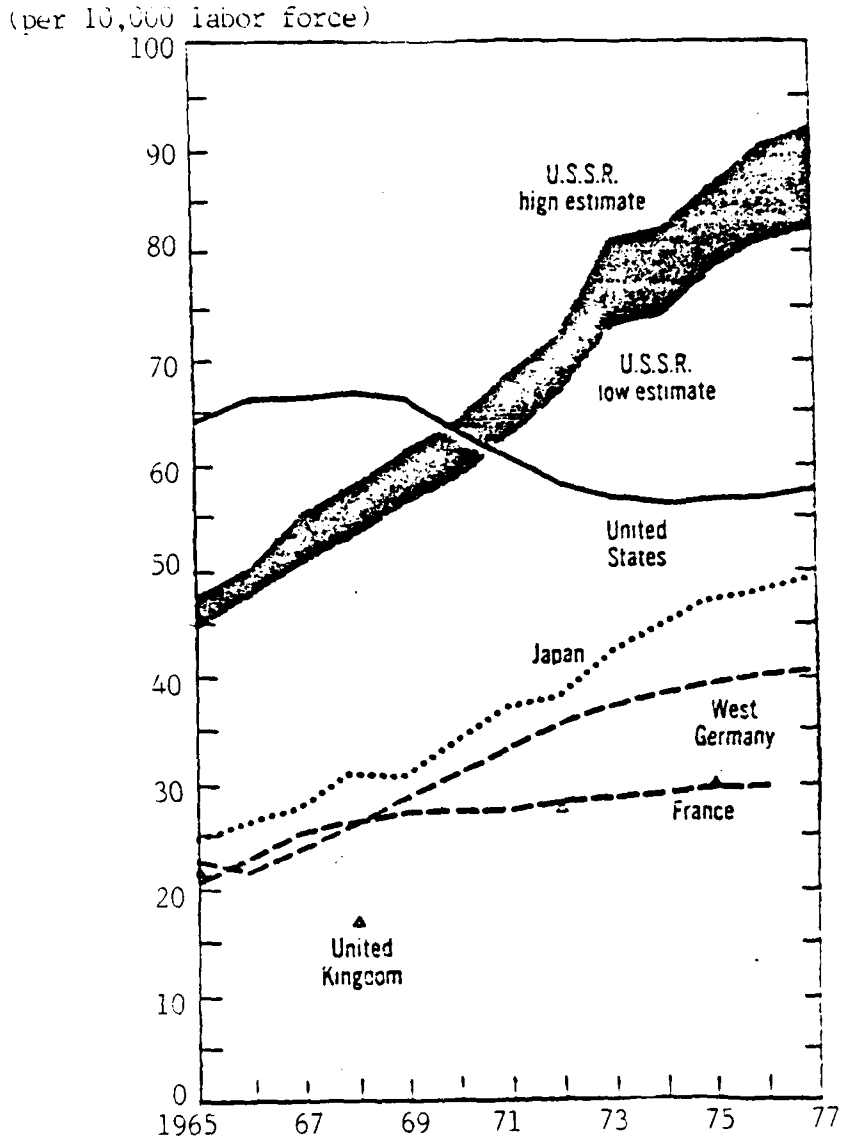
A further indication of the level of Soviet interest in pursuing research and development is the size of their research and development force of scientists and engineers. The Soviet Union surpasses the United States both in absolute numbers of scientists and engineers engaged in research and development and in the number of scientists and engineers conducting research and development activities per 10,000 of the labor force population. The latter trend for the period 1965-77 can be seen in Figure 2. [Ref. 6: p. 8]



Source: <u>Science Indicators 1978</u>

National expenditures for performance of R&D as a percent of gross national product (GNP) by country: 1961-78

FIGURE 1



Source: Science Indicators 1978

Scientists and engineers engaged in R&D per 10,000 labor force population by country: 1965-77

FIGURE 2

The results of the Soviets' intense efforts in research and development over the past thirty years have been marginal in civilian related technologies, impressive in the military sphere, and occasionally startling. The United States was surprised by the rapidity with which the Soviet Union developed and deployed strategic weapons and shocked by the launching of the first Sputnik on October 4, 1957. Less dramatic, but perhaps more indicative of the status of the general technological base, are the advances in the Soviets' conventional and tactical military forces. A comparison of technology levels in deployed military systems shown in Table I [Ref. 5: p. 52] suggests that the Soviets' efforts in research and development have been highly successful in the military sector. This success, in fact, led Richard D. DeLauer, Under Secretary of Defense for Research and Engineering, to present the following testimony before the House Armed Services Committee in March 1982.

> Mr. Chairman, I'm frankly impressed with what (the Soviets have) done. Our past technology lead can no longer offset the quantity deficiency by itself--the numerical disadvantage in most categories of weapons is too great, and our advantage in most deployed technologies is too small. This is the reason for our emphasis in the FY 1983 RD&A budget and programs in deploying increased quantities of operationally effective systems as rapidly as possible, and on increasing our ability to infuse our emerging technology into deployed systems more rapidly. [Ref. 5: p. 14]

The Soviet Union's progress in military technology has been substantial but, interestingly, these advancements are

TABLE I

Relative US/USSR Technology Level in Deployed Military Systems

Deployed System	US Superior	US-USSR Equal	USSR Superior
<u>Strategic</u>			
ICBM		X	
SSBN		<--X	
SLBM	X-->		
Bomber	X		
SAMs			X
Ballistic Missile Defense			X
Anti-satellite			X
Cruise Missile	X		
<u>Tactical</u>			
Land Forces			
SAMs (including naval)		X	
Tanks		X	
Artillery		X	
Infantry Combat Vehicles			X
Anti-tank Guided Missiles		X	
Attack Helicopters		X	
Chemical Warfare			X
Theater Ballistic Missiles		X	
Air Forces			
Fighter/Attack Aircraft	X-->		
Air-to-Air Missiles	X		
PGM	X-->		
Air Lift	X		
Naval Forces			
SSNs		X	
Anti-Submarine Warfare	X-->		
Sea-based Air	X		
Surface Combatants		X	
Cruise Missiles		X-->	
Mine Warfare			X
Amphibious Warfare			
<u>C^3I</u>			
Communications		X	
Command and Control		X	
Electronic Countermeasure/ECCM		X	
Surveillance and Reconnaissance	X-->		
Early Warning	X-->		

Arrows denote that the relative technology level is changing significantly in the direction indicated.

Source: Committee on Armed Services, U.S. Congress, House

not mirrored in either the civilian sector or in basic technology. Hedrick Smith and Robert Kaiser address the dearth of technological conveniences available to civilians in their accounts of experiences in the Soviet Union [Ref. 7 and Ref. 8]. The standard of living of most Soviet citizens would be considered rather backward by American standards. The Soviet Union's priority for military requirements is one factor which accounts for this lag in the civilian sector. But the Soviets also lag in military-related basic technologies. Table II [Ref. 5: p. 51] compares the Soviet and American standing in basic technologies which have the greatest potential for significantly changing military capabilities in the next ten to twenty years. The United States has maintained a general lead in these basic technologies although, as indicated, this advantage is decreasing. A comparison of the status of basic technologies depicted in Table II with the status of deployed technologies depicted in Table I serves to emphasize the disparity between the Soviet achievements in these two levels of technological development.

The disparity is suggestive of the Soviet Union's heavy reliance on a steady infusion of Western technology. They have been extremely active in acquiring Western technology through both overt and covert methods, and have proven adept at reverse engineering high technology products. Yet,

TABLE II

Relative US/USSR Standing in the 20 Most Important
Basic Technology Areas

Basic Technologies	US Superior	US-USSR Equal	USSR Superior
Aerodynamics/Fluid Dynamics		X	
Automated Control	X		
Conventional Warhead (including Chemical Explosives)			X
Computer	X		
Directed Energy		X	
Electro-optical Sensor (including IR)	X-->		
Guidance and Navigation	X-->		
Microelectronic Materials and Integrated Circuit Manufacture	X		
Nuclear Warhead		X	
Optics	X-->		
Power Sources (Mobile)			X
Production/Manufacturing	X		
Propulsion (Aerospace)	X-->		
Radar Sensor	X-->		
Signal Processing	X-->		
Software	X		
Stealth (Signature Reduction Technology)	X		
Structural Materials (light weight, high strength)		<--X	
Submarine Detection (including Silencing)	X-->		
Telecommunications	X		

Arrows denote that the relative technology level is changing significantly in the direction indicated.

Source: Committee on Armed Services, U.S. Congress, House

despite the Soviet Union's ability to absorb Western technology into deployed military systems and in spite of the extensive resources dedicated to developing research capabilities, the Soviet Union lags substantially in basic technology and basic research. The infusion of Western technology has not invigorated Soviet basic research to self-sufficiency.

Why does Soviet basic research continue to lag dramatically, forcing a continued reliance on foreign technology to remain competitive in the military sphere? This is the central question to be addressed by this paper. Many factors are involved in determining the viability of Soviet research. Significant among these is the weakness of the technological base, which hampers the development of laboratory equipment and the availability of computer and administrative support equipment. Another significant element is the distinct separation between military and civilian research efforts, which restricts interaction among the scientific communities. Additionally, Russian culture and Soviet ideology must be considered as major determinants in Soviet research capability.

This paper will focus on the impact of culture and ideology on Soviet science, using Thomas Kuhn's analysis of the scientific process as a schema. Science is an activity involving both the scientific community and the external

influences of society. This implies that, rather than a purely objective pursuit, science is a process permeable to cultural and ideological influences. The ability of a nation to conduct scientific research will therefore be dependent in some way on its cultural and ideological attributes. My thesis is that Russian culture and Soviet ideology are among the factors impelling the Soviet Union's dependence on Western technology.

II. THE SCIENTIFIC PROCESS

A. OBSERVATION AND OBJECTIVITY

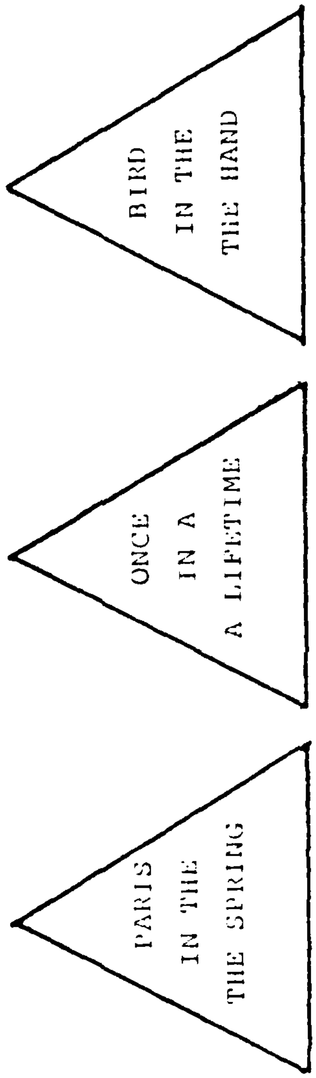
Science is commonly held to be an objective and rigorous investigation of natural processes. Even under the scrutiny of science, however, objectivity in the sense of an external reality or "truth" is illusive. Scientific theories attempt to explain natural events by observing phenomena under carefully controlled conditions and interpreting these observations within a logical conceptual framework. Because of the demands within the scientific community for precise documentation of these controlled experiments, the requirement for replication of results, and the expectation of agreement between hypothetical and observed data, science has gained a reputation for objectivity. But neither the act of observation nor the conceptualization of a theoretical framework is an objective process.

Observation is a process in which an external stimulus evokes a physical reaction which, after neural processing, registers as a sensory input or datum. Medical and psychological experiments indicate that the effect of the neural processing in modifying the stimuli is significant. In transforming external stimuli to data, the neural process is both selective and interpretive. The selectivity of the

process was demonstrated in an experiment in which subjects were shown Figure 3 for a short time. As Figure 3 indicates, each of the triangles contained a well-known phrase but repeated one of the articles, "the" or "and". Most subjects, however, were unaware of the repetition unless shown the phrases repeatedly or for prolonged periods [Ref. 9: p. 34]. The neural process acted as a filter selecting the stimuli to be acknowledged.

Another experiment, conducted by J.S. Bruner and Leo Postman in 1949, demonstrated the modification of external stimuli by the neural process. Subjects were exposed to a series of playing cards which included both normal playing cards and cards which mixed suits and colors (e.g. red spades). After an initial exposure almost all subjects identified both the normal and the mixed cards as normal cards (e.g. a red spade would be perceived as a black spade). Again, it required increased exposure before the subjects were able to identify the inclusion and the nature of the discrepancies. Some subjects never adjusted to the inclusion of these cards [Ref. 10: pp. 62-3]. In this case, the neural process modified the stimuli of the discrepant cards causing the acknowledged data to conform to expectations.

Both of these experiments utilized sets of stimuli about which the subjects had strong preconceptions--the first



Source: <u>Strategic Military Deception</u>

Experiment in perceptual selectivity

FIGURE 3

experiment involved cliche phrases and the second experiment employed common playing cards. Thus, the subjects, based on prior experiences, had already constructed mental images of the phrases and cards before participating in the experiments. As a result of the subjects' repeated prior experiences with these phrases and cards, their mental images had become well established and had acquired an inertial resistance to change. When exposed to a very similar set of stimuli, the subjects' neural processes selected and modified the stimuli such that the resultant data conformed to the established image or pattern. To overcome the inertia of the image, repeated or prolonged exposures to the discrepant stimuli was necessary. Once the discrepant stimuli acquired, either incrementally or from a single major impact, enough energy to overcome the inertia, then the image itself was modified to subsume the new data and the discrepancies were perceived. [Ref. 11: pp.5-10]

The advantage of this process of modification and filtration is that the mind is able to assimilate large volumes of stimuli fairly quickly (100 bits per second). Incoming stimuli are transformed into data sets which can be compared to the established image or pattern. Based on these similarity patterns, the mind can react to the stimuli more rapidly. The "disadvantage" to this process is that the stimuli must be transformed by the neural process before

being relevant to the mind as data. The implication is that the observation process cannot be objective. The "reality" of the external stimuli is not perceived directly, but rather through the veil of neural process. Stimuli may be filtered out as superfluous, or may be modified to conform to recognizable patterns--and this process occurs before the mind consciously registers the observation. As previously noted, however, sufficiently energetic discrepant stimuli can eventually modify the image involved in this process. Thomas Kuhn points out that

> Nor are responses like these entirely innate. One can learn to discriminate colors or patterns which were indistinguishable prior to the training. To an extent still unknown, the production of data from stimuli is a learned procedure. After the learning process, the same stimulus evokes a different datum. [Ref. 1: pp. 308-9]

In other words, education can adjust the image and the subsets of similarity patterns.

The construction of shared images and similarity patterns through education and group experiences is one of the attributes which distinguishes a professional community. Kuhn denotes these similarity patterns for the scientific community as paradigms [Ref. 1: pp. 293-319]. The science student is exposed to explicitly stated theories and historically relevant experiments and then assigned problem sets which demonstrate the principles involved. These problem sets demonstrate to the student specific applications of the general, formal symbolic expressions. As an

example, Kuhn points out that the specific application of the general expression, f=ma, involves symbolic substitution. Thus, force, f, becomes mass times gravity, mg, in the more specific application of free fall problems [Ref. 1: p. 299]. Problem sets exercise for the student the relationships enveloped by the symbolic expressions. In addition to demonstrating these specific applications, the problem sets serve as exemplars to which the science student can refer when confronted with new problems. The new problem can then be solved by analogous application. As exemplars, such problem sets are major determinants in constructing the shared images of the scientific communities.

> Acquiring an arsenal of exemplars, just as much as learning symbolic generalizations, is integral to the process by which a student gains access to the cognitive achievements of his disciplinary group. [Ref. 1: p. 307].

The construction and transmission of shared images is vital to shaping scientific communities and the strength of these shared images contributes to the effectiveness of the scientific process. Traditionally, training in the natural sciences has been characterized by the rigorous study of approved science textbooks. These textbooks typically present currently accepted theories, the supporting experimental evidence, and problem sets as described above. Science textbooks do not consider the periods of controversy

leading to the community's acceptance of a theory, nor do they present research products in an unrefined state representative of professional journals and writings. Rather, textbooks are designed to efficiently inculcate the student in the dicta of his field of study [Ref. 1: pp. 228-9]. This rigorous process of indoctrination, with its minimal exposure to alternative theories, generates a set of images which enjoy a high degree of conformity among the members of the scientific community. The cohesiveness of the shared images increases further within the various subgroups of scientific specialties. [Ref. 1: p. 307]

B. NORMAL AND EXTRAORDINARY SCIENCES

The ability of the scientific community to generate and transmit a body of images among its members is one of the necessary characteristics for conducting the phase of research which Kuhn has termed "normal science". Normal science is premised on the accepted theories and paradigms incorporated in the shared images of the community. The existing theories provide the scientist a basis for formulating hypotheses and designing experiments to test them. Kuhn describes three major types of challenges addressed by normal science. The first challenge is to bring theory and observation into closer agreement either by making minor adjustments to the existing theory or by developing new techniques of observation. The second

challenge is to extend existing theory to untried areas of application. The third challenge is to collect the volumes of specific data which support the application and extension of existing theory [Ref. 1: p. 233]. These challenges confront the scientist as puzzles to be solved within the framework of accepted theory.

The "puzzle solving tradition" of normal science [Ref. 10: pp. 35-42] is a powerful vehicle for scientific advancement. The consensus among the members of a mature scientific specialty enables the scientist to concentrate on narrowly defined problems derived from existing theory. The existing theories not only clearly define for the scientist the nature of the puzzles, but also provide him with a framework for their solutions by generating a web of expectations. The power of this consensus differentiates the natural, mature sciences from the arts and social sciences.

> ... History strongly suggests that, though one can practice science--as one does philosophy or art or political science--without a firm consensus, this more flexible practice will not produce the pattern of rapid consequential scientific advance to which recent centuries have accustomed us.... Except under quite special conditions, the practitioner of a mature science does not pause to examine divergent modes of explanation or experimentation. [Ref. 1: p. 232]

The consensus characteristic of normal science provides the foundation for another phase of research which Kuhn terms "extraordinary science". As previously noted,

existing theories provide the scientist with both the puzzles and some expectation of the nature of their solutions. The web of expectations serves as a frame of reference against which the scientist can determine the validity of his experiments. Thus, if the experimental results do not conform to the expectations generated by existing theory, it is not the validity of the theory which is questioned but the validity of the experiment [Ref. 1: p. 270-1]. A number of explanations may account for experimental discrepancies without impairing existing theory.

> In any case, experience has repeatedly shown that, in overwhelming proportion, these discrepancies disappear upon closer scrutiny. They may prove to be instrumental effects, or they may result from previously unnoticed approximations in the theory, or they may, simply and mysteriously, cease to occur when the experiment is repeated under slightly different conditions. More often than not the efficient procedure is therefore to decide that the problem has "gone sour", that it presents hidden complexities, and that it is time to put it aside in favor of another. [Ref. 1: p. 202]

The assurance that existing theory provides the scientist--i.e., that discrepancies can be accounted for within the accepted framework of expectations--enables him to discount the majority of discrepancies thereby preventing him from being distracted or inundated by anomalies which "...occur so regularly that no scientist could bring his research problems to a conclusion if he paused for many of them." [Ref. 1: p. 202]

Not all discrepancies can be accounted for by the existing theory, however. Over time, normal science will generate anomalous data which, either by the weight of incremental accumulation or by the imperative commanded by a single central contradiction, will threaten the consensus enjoyed by the existing theory. The affected specialist community may then experience a period of crisis. The existing theory has proven to be inadequate to account for the anomalies and new theories are constructed and offered as alternatives. This is a period of conflict in which the old theory and new theories compete for the endorsement of the specialist community. During such a period, the alternative theories may be prolific and their overall implication uncertain. What, then, is the process by which the community adopts a new theory? Kuhn discusses five characteristics which serve as primary criteria of selection--accuracy, consistency, scope, simplicity, and fruitfulness [Ref. 1: p. 322]. These criteria are not exclusive nor are they consistently weighted as to priority. Competing theories may, for instance, offer similar degrees of agreement with data determined within existing instrumental capabilities. Such a situation occurred during the debate between the caloric and dynamical theories of heat.

> In their abstract structure and in the conceptual entities they presuppose, these two theories are quite different and, in fact, incompatible. But, during the years when the two vied for the allegiance of the scientific community, the theoretical predictions that could be derived from them were very nearly the same. [Ref. 1: p. 200]

As Kuhn points out, this is not an unusual dilemma to occur during periods of conflict. For a theory to even be considered by the scientific community its predictive results must reasonably agree with previous experimental data [Ref. 1: p. 201]. Other criteria must then be applied in the individual scientist's selection of a theory. Since criteria and priorities vary with the individual, group allegiance to a new theory will evolve gradually and increase as new supporting evidence is developed. Adherence to the old theory may, however, prove tenacious, especially among the older scientists steeped in the traditional image. Max Planck noted that,

> a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it. [Ref. 10: p. 151]

Eventually, however, the scientific community will reach a consensus and generate a revised shared image. Textbooks are then rewritten to reflect the "new scientific truth" and the legitimacy of the shared image is preserved.

> In short, (textbooks) have to be rewritten in the aftermath of each scientific revolution, and, once rewritten, they inevitably disguise not only the role but the very existence of the revolutions that produced them. [Ref. 10: p. 137]

This reformulation of the shared image then provides the foundation for a new period of normal science.

Kuhn suggests that the scientific process is most successful when normal science achieves an optimum balance between inertial resistance to change and receptivity to alternate theories. This balance is what Kuhn terms "the essential tension". The inertia of the shared image predominant in normal science is necessary both to structure the research of the scientist and to provide a context in which expectation and anomaly are relevant. While expectations may suppress the perception of anomalies as in the two experiments involving playing cards and cliches, it is against the backdrop of expectations that anomalies finally become apparent. Once apparent, the significance of the anomaly must be weighed against the inertia of the community image. If the inertial resistance is too great, alternative theories will not be considered by the community. If the inertial resistance is insufficient and alternative theories are too readily considered, then the consensus will collapse and the validity of a theory will not be fully tested or exploited. [Ref. 1: pp. 234-5 and pp. 332-3]

C. CHARACTERISTICS OF NORMAL AND EXTRAORDINARY SCIENCES

The essential tension between inertia and change is determined by the composition of the particular scientific community. As previously noted, each scientist must measure

the desirability of competing theories against a value system. This value system will be strongly influenced by the scientist's indoctrination in the shared image; however, personal characteristics will result in deviations from the group norm [Ref. 1: p. 333]. Though scientific groups as a whole tend to greater cohesiveness and lower tolerance to change in comparison to other communities, these characteristics will vary from one scientific group to another. The disintegration and subsequent reformulation of consensus therefore occurs incrementally at a rate determined by group composition.

While consensus disintegration and reformulation occur within a group context, the acknowledgement of anomaly and the construction of alternate theories are dependent on the characteristics of the individual scientist. Different traits are conducive to normal and extraordinary periods of research. Normal science is characterized by convergent thought and a strong consensus. The shared image acts as a lens focusing the efforts of the community on precise problem areas with the focal resolution dependent on the strength of consensus. The normal scientist, firmly committed to the shared image, is adept at solving puzzles through clever applications of that image rather than devising revolutionary alternatives to the image. He is able to focus his attention on specific problems without being distracted by most anomalies.

A second characteristic of normal science is the ingrained use of analogy to solve problems. As previously discussed, paradigms both enhance the science student's understanding of a general principle and provide him with exemplars to apply in new situations. The use of paradigms, then, in problem solving is a form of pattern recognition.

> Once a new problem is seen to be analogous to a problem previously solved, both an appropriate formalism and a new way of attaching its symbolic consequences to nature follow. Having seen the resemblance, one simply uses the attachments that have proved effective before. That ability to recognize group-licensed resemblances is ... the main thing students acquire by doing problems, whether with pencil and paper or in a well-designed laboratory. [Ref. 1: p. 306]

Proficiency at recognizing the similarities between new problems and established patterns is therefore desirable in normal science.

Convergent thought, consensus, and pattern recognition are attributes conducive to normal science and are the traits reinforced by the traditional style of science education. By expunging references to historical periods of conflict, requiring rigorous indoctrination in accepted theories, and exposing the science student to a paradigm method of problem solution, the scientific community ensures the continuation of a strong consensus. After admitting new members into the scientific community, peer standards and acceptance serve to preserve consensus.

> It is ... important that group unanimity be a paramount value, causing the group to minimize the occasions for conflict and to reunite quickly about a single set of rules for puzzle solving even at the price of subdividing the specialty or excluding a formerly productive member. [Ref. 1: p. 291]

Normal science, then, is characteristically "... a highly convergent activity based firmly upon a settled consensus acquired from scientific education and reinforced by subsequent life in the profession." [Ref. 1: p. 227]

The attributes conducive to extraordinary science are quite different from those of normal science. The scientist must perceive anomalies generated by normal research and must be receptive to their possible implications. These are traits associated with divergent thinking. The shared image is not so deeply ingrained and perception of anomaly occurs at a lower threshold. Having perceived the anomaly, the divergent thinker, less secure in the validity of the shared image, is more likely to be distracted and to investigate the anomalous phenomenon. Upon investigation, most of these anomalies will be accounted for by existing theory and therefore have consumed the scientist's time and effort without significant results. However, some anomalies will bear the seeds of scientific revolution and initiate the metamorphosis from normal to extraordinary science.

> But not all anomalies do respond to minor adjustments of the existing conceptual and instrumental fabric. Among those that do not are some which, either because they are particularly striking or because they are educed repeatedly in many different laboratories, cannot be

> indefinitely ignored. Though they remain unassimilated, they impinge with gradually increasing force upon the consciousness of the scientific community. [Ref. 1: p. 262]

With the validity of the existing theory in doubt, the scientist must create new theories. This form of creativity differs from the creative ability of the normal scientist. Rather than creatively applying the patterns of existing theory, the scientist must escape the existing patterns and construct a new image. The same data is reorganized to reveal new relationships in a process similar to a shift in visual gestalt [Ref. 10: p. 85]. "One central aspect of any revolution is, then, that some of the similarity relations change" [Ref. 10: p. 200]. Thus, while normal science is characterized by proficiency in pattern recognition, extraordinary science is characterized by proficiency in pattern construction.

The ability to perceive anomaly and to construct alternate theories is inversely related to the entrenchment of the shared image. Typically, discoveries in the natural sciences are attributed to scientists less acclimatized by accepted theory [Ref. 12: pp. 497-559]. These are scientists who have been sufficiently exposed to accepted theory to appreciate the expectations of that theory, without having become entrapped by those expectations. Thus,

almost always the men who achieve these fundamental inventions of a new paradigm have been either very young or very new to the field whose paradigm they change. [Ref. 10: p. 90]

A strong commitment to the shared image, so vital to normal science, therefore restrains extraordinary science in three phases. First, it raises the threshold of perception to exclude most anomalies. Second, it is more conducive to pattern recognition than to pattern construction. And third, it inhibits the community's acceptance of newly constructed theories.

Both sets of characteristics, however, are essential to maintaining the cyclical progress of scientific research. Anomalies can emerge only within the context of normal science and extended periods of normal research are necessary preludes to periods of extraordinary science [Ref. 1: p. 227]. The scientific community, then, must be composed of both divergent and convergent thinkers for the cycle of normal and extraordinary periods to occur. And,

> since these two modes of thought are inevitably in conflict, it will follow that the ability to support a tension that can occasionally become almost unbearable is one of the prime requisites for the very best sort of scientific research. [Ref. 1: p. 226]

For a society seeking to maximize scientific progress, given limited resources, the nature of this tension, and of the scientific process in general, holds implications for resource allocation and science management. The backbone of the scientific community must be the cadre of normal

scientists. The education of the science student should therefore adhere to the traditional approach conducive to firmly implanting a shared image. Admittance into the scientific community should then be based on rigorous standards and group approval--for, ultimately, the scientific community is its own arbiter, "... (constituting) a special subculture, one whose members are the exclusive audience for, and judges of, each other's work" [Ref. 1: p. 119]. The group, however, must be flexible enough to tolerate a divergent element. This flexibility is exercised not only in admitting divergent thinkers to the ranks of the community, but in permitting a degree of lateral mobility between scientific specialties and upward mobility for the younger scientist.

There is no formula to dictate the optimum distribution curve for the characteristics of tolerance and cohesiveness that a scientific community should possess. As previously noted, scientific groups tend to display a lower tolerance to change and a greater cohesiveness than do other professional communities; but specific distributions have not been established. Guidelines, however, have been suggested by economists for more efficient science management. In a RAND corporation research study, Charles Hitch and Roland McKean proffer the following guidelines for military research and development management. First, the

community should support some duplication of research effort along diverse approaches. The areas of duplication should be determined by a) the critical need in a specific research area (e.g. the early development of the atom bomb), b) the greater uncertainty (i.e. lack of consensus) in a given area, c) the relative inexpense of the duplication ["There should be more duplication, the cheaper it is to duplicate." Ref. 13: p. 250], and d) the possibility of qualitatively different alternatives accruing from duplication. As to the number of diverse approaches to be supported,

> no one knows enough to give precise answers. Some original and suggestive theoretical analysis indicates that in many circumstances there are greater gains from pursuing two, three, or four paths, but rapidly diminishing returns from further duplication. [Ref. 13: p. 249]

Another guideline offered by Hitch and McKean is the need to decentralize and to avoid premature overspecification. The bureaucratic tendency to increase centralization and direction is antithetical to handling the uncertainties inherent in basic research. Thus,

> 'the best person to decide what research work shall be done is the man who is doing the research. The next best is the head of the department. After that you leave the field of best persons and meet increasingly worse groups. The first of these is the research director, who is probably wrong more than half the time. Then comes a committee, which is wrong most of the time. Finally, there is a committee of company vice-presidents which is wrong all the time.' [Ref. 13: p. 254]

Hitch and McKean suggest other guidelines as well--such as the advantages to be gained from competition and the need

for emphasis on the early stages of research--but the critical element in these guidelines and in science management in general remains elusive. What is the optimum balance between convergent and divergent thinking to maximize scientific advance? How much duplication should then be encouraged without wasting resources? How much independence should the scientist enjoy from the judgement of his peers? All these questions relate to the "essential tension" which Kuhn posits as the prime mover for scientific advancement. While Kuhn's analysis does not provide a quantitative means of determining the desirable level of tension to be maintained, it does suggest the characteristics which must be present in the scientific community for a tension to exist. Thus it is possible to consider if a particular scientific community displays those characteristics necessary for rapid scientific progress.

III. THE PERMEABILITY OF SCIENCE

The mechanism of scientific progress described in the previous chapter reveals several points at which science is permeable to cultural influences. Culture affects both the characteristics internal to the scientific community and those of the parent society in which the scientific community functions. Within the scientific community, culture significantly affects the distribution patterns of tolerance and cohesiveness traits. Within the larger society, culture influences the type of support that society will grant and the requirements it will levy upon the scientific community. These internal and external cultural influences may radically skew the community's ability to generate and maintain a level of tension sufficient for scientific progress.

A. UNCERTAINTY AVOIDANCE INDEX

Various indices have been developed to compare cultural norms. One such index compares the tolerance for uncertainty that is characteristic of different cultures [Ref. 14: pp. 153-212]. In this context, the uncertainty of the future generates anxiety levels within a society.

> Different societies have adapted to uncertainty in different ways. Ways of coping with uncertainty belong to the cultural heritage of societies and they are

> transferred and reinforced through basic institutions like the family, the school, and the state. They are reflected in collectively held values of the members of a particular society. Their roots are non-rational, and they may lead to collective behavior in one society which may seem aberrant and incomprehensible to members of other societies. [Ref. 14: p. 154]

Thus, cultures with low tolerance construct social mechanisms to reduce the threat of uncertainty. Tables III [Ref. 14: p. 184] and IV [Ref. 14: pp. 176-7] list some of the characteristics and social mechanisms associated with low tolerance (high uncertainty avoidance) and high tolerance (low uncertainty avoidance) cultures.

Several attributes relating to uncertainty avoidance are relevant to the scientific process. Consensus, a fundamental element for normal science, is ascribed to cultures with low tolerance for uncertainty. High tolerance cultures, on the other hand, display many of the attributes conducive to extraordinary scientific advancement. These high tolerance cultures abide by the conflict, competition, and risk inherent to periods of extraordinary scientific research. In addition, greater job mobilitiy, both upward and lateral, is characteristic of high tolerance cultures, thus encouraging the fresh outlook necessary to extraordinary science. Low tolerance cultures, then, generate convergent characteristics which support normal science but inhibit extraordinary science; while high tolerance cultures generate the divergent characteristics requisite to

TABLE III

The Uncertainty Avoidance Societal Norms

LOW UAI	HIGH UAI
* The uncertainty inherent in life is more easily accepted and each day is taken as it comes.	* The uncertainty inherent in life is felt as a continuous threat that must be fought.
* Ease, lower stress.	* Higher anxiety and stress.
* Time is free.	* Time is money.
* Hard work is not a virtue per se.	* Inner urge to work hard.
* Weaker superegos.	* Strong superegos.
* Aggressive behavior is frowned upon.	* Aggressive behavior of self and others is accepted.
* Less showing of emotions.	* More showing of emotions.
* Conflict and competition can be contained on the level of fair play and used constructively.	* Conflict and competition can unleash aggression and should therefore be avoided.
* More acceptance of dissent.	* Strong need for consensus.
* Deviance is not felt as threatening; greater tolerance.	* Deviant persons and ideas are dangerous; intolerance.
* Less nationalism.	* Nationalism.
* More positive toward younger people.	* Younger people are suspect.
* Less conservatism.	* Conservatism, law and order.
* More willingness to take risks in life.	* Concern with security in life.
* Achievement determined in terms of recognition.	* Achievement defined in terms of security.

TABLE III. (Continued)

Low UAI	High UAI
* Relativism, empiricism.	* Search for ultimate, absolute truths and values.
* There should be as few rules as possible.	* Need for written rules and regulations.
* If rules cannot be kept, we should change them.	* If rules cannot be kept, we are sinners and should repent.
* Belief in generalists and common sense.	* Belief in experts and their knowledge.
* The authorities are there to serve the citizens.	* Ordinary citizens are incompetent versus the authorities.

Source: Culture's Consequences

TABLE IV

A Summary of Connotations of Uncertainty Avoidance Index Differences Found in Survey Research

Low UAI Countries	High UAI Countries
* Lower anxiety level in population.	* Higher anxiety level in population.
* Greater readiness to live by the day.	* More worry about the future.
* Lower job stress.	* Higher job stress.
* Less emotional resistance to change.	* More emotional resistance to change.
* Less hesitation to change employers.	* Tendency to stay with the same employer.
* Loyalty to employer is not seen as a virtue.	* Loyalty to employer is seen as a virtue.
* Preference for smaller organizations as employers.	* Preference for larger organizations as employers.
* Smaller generation gap.	* Greater generation gap.
* Lower average age in higher level jobs.	* Higher average age in higher level jobs: gerontocracy.
* Managers should be selected on other criteria than seniority.	* Managers should be selected on the basis of seniority.
* Stronger achievement motivation.	* Less achievement motivation.
* Hope of success.	* Fear of failure.
* More risk-taking.	* Less risk-taking.
* Stronger ambition for individual advancement.	* Lower ambition for individual advancement.

TABLE IV. (Continued)

Low UAI Countries	High UAI Countries
* Prefers manager career over specialist career.	* Prefers specialist career over manager career.
* A manager need not be an expert in the field he manages.	* A manager must be an expert in the field he manages.
* Hierarchical structures of organizations can be by-passed.	* Hierarchical structures of organizations should be clear and respected.
* Preference for broad guidelines.	* Preference for clear requirements and instructions.
* Rules may be broken for pragmatic reasons.	* Company rules should not be broken.
* Conflict in organizations is natural.	* Conflict in organizations is undesirable.
* Competition between employees can be fair and right.	* Competition between employees is emotionally disapproved of.
* More sympathy for individual and authoritative decisions.	* Ideological appeal of consensus and of consultative leadership.
* Delegation to subordinates can be complete.	* However, initiative of subordinates should be kept under control.
* Higher tolerance for ambiguity in perceiving others.	* Lower tolerance for ambiguity in perceiving others.
* More prepared to compromise with opponents.	* Lower readiness to compromise with opponents.
* Acceptance of foreigners as managers.	* Suspicion toward foreigners as managers.
* Larger fraction prepared to live abroad.	* Fewer people prepared to live abroad.

TABLE IV. *(Continued)*

Low UAI Countries	High UAI Countries
* Higher tolerance for ambiguity in looking at own job.	* Lower tolerance for ambiguity in looking at own job.
* Citizens optimism about ability to control politicians' decisions.	* Citizens pessimism about ability to control politicians' decisions.
* Employee optimism about the motives behind company activities.	* Employee pessimism about the motives behind company activities.
* Optimism about people's amount of initiative, ambition, and leadership skills.	* Pessimism about people's amount of initiative, ambition, and leadership skills.

Source: Culture's Consequences

extraordinary science but may yield insufficient cohesiveness to support normal science.

B. HIGH AND LOW CONTEXT CULTURES

Anthropologist Edward Hall provides another index with which to compare cultures [Ref. 15]. In Hall's analysis, cultures can be compared against a continuum ranging from high to low context. Hall suggests that higher contexture is related to greater pattern recognition capacities [Ref. 15: p. 120]. This pattern recognition process is reflected in the communication styles of high and low context cultures. Low context communications are linear, explicit, and detailed. In contrast,

> (High context) transactions feature preprogrammed information that is in the receiver and in the setting, with only minimal information in the transmitted message.... (High context) communication ... is economical, fast efficient, and satisfying; however, time must be devoted to programming. If this programming does not take place, the communication is incomplete. [Ref. 15: p. 101]

High context cultures, then, hinge on a strong indoctrination in a shared image. Assured of the mutuality of this image, high context interactions can assume pattern relationships based on fewer cues.

> ... (The) only way to increase information-handling capacity without increasing the mass and complexity of the system is to program the memory of the system so that less information is required to activate the system, i.e., make it more like the couple that has been married for thirty-five years. [Ref. 15: pp. 85-6]

High context cultures, then, are compatible with normal science. The integral role of the shared image and the heavy utilization of pattern recognition are traits common to both normal science and high context cultures. This commonality implies that high context cultures are less conducive to extraordinary science. "(High context) actions are by definition rooted in the past, slow to change, and highly stable" [Ref. 15: p. 93]. Low context systems, on the other hand, are more receptive to change and to new ideas.

> Those of us in the West who are used to having to struggle with the complexities of (low context) systems can, when we are confronted with something new, be quite creative about it and not require an inordinate amount of detailed programming. (High context) people can be creative within their own system but have to move to the bottom of the context scale when dealing with anything new, whereas (low context) people can be quite creative and innovative when dealing with the new but have trouble being anything but pedestrian when working within the bounds of old systems. [Ref. 15: p. 127]

Thus, the creativity of the high context scientist is that of the puzzle solver proficient at pattern recognition; while the creativity of the low context scientist is in constructing new patterns.

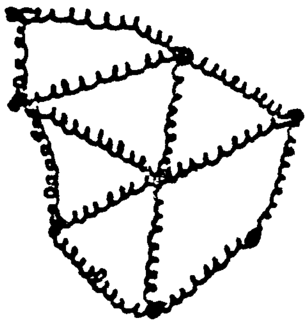
C. THE JAPANESE EXAMPLE

Comparing cultures, Hall considers the United States to fall toward the low end of the context scale while Japan falls at the high context end. Makoto Kikuchi, director of the Sony Research Center in Yokohama, Japan, provides an

analysis of Japan's research style which illustrates the impact of high context culture on a society's scientific capability. In his analysis, Kikuchi attributes Japan's impressive success in exploiting solid-state electronics technology to their style of scientific research. He considers four cultural factors to significantly influence this style--consensus, pattern recognition capability, education techniques, and flexibility. Consensus is intrinsic to the Japanese culture. Kikuchi likens Japanese society to a set of small stones closely connected by strong springs (Figure 4). More individualistic societies, such as the United States, are represented by large stones only loosely connected. The size of the stones indicates the importance of the individual relative to society as a whole. The strength of the springs represents the degree of social cohesion.

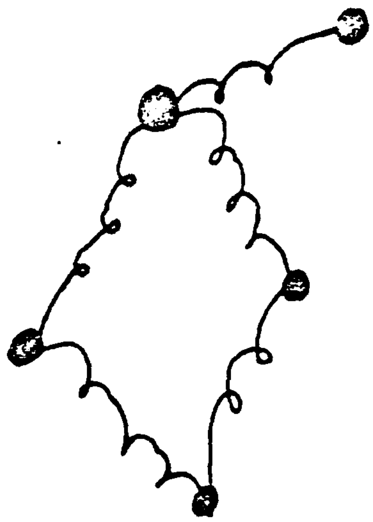
> If you agitate one corner of a network like the one in Figure (4)a, everything will start to oscillate within a short time. "Consensus," represented by an in-phase oscillation of the entire system will soon be attained, and the time constant for information propagation will be short. In a network like Figure (4)b, on the other hand, when you agitate one corner the large mass of the stones and the weakness of the springs defeat any attempt to induce a system-wide oscillation. [Ref. 16: p. 45]

One of the significant factors shaping the Japanese style of research, then, is the consensual base characteristic of normal science.



A.

B.



Source: "Creativity and Ways of Thinking: The Japanese Style," Physics Today

Representations of individualistic and consensus oriented societies

FIGURE 4

The second element which Kikuchi considers is pattern recognition. Research suggests that Japanese possess a stronger pattern recognition capability while Americans are stronger in numerical and logical operations [Ref. 16: pp. 48-9]. Pattern recognition is another quality necessary for normal science.

Education in Japan reinforces consensus and pattern recognition capabilities. Kikuchi points out that the Japanese word "manabu" (to learn) was originally "manebu" (to imitate) [Ref. 16: p. 44]. The traditional method of learning through imitation is reflected in the current style of education. Memorization and homogeneity are emphasized at the expense of independent creative thinking.

> Education is very homogenous in Japan. Courses and text books for the primary and high schools are carefully standardized so that students are taught the same things to the same level at the same time of the year from Hokkaido to Okinawa. [Ref. 16: p. 44]

Entrance examination are a primary concern in the Japanese system and dominate the student's education.

> Skills for passing examinations ... consist of memorizing a large number of sophisticated problems and remembering a long list of "keys" for solving the trick questions that examiners are fond of setting. [Ref. 16: p. 44]

The Japanese system with its stress on homogeneity and memorization is an effective mechanism for inculcating a shared image. The examination process using "large numbers of sophisticated problems" and "keys" trains the student to

use paradigm-based solutions and relies heavily on his ability to recognize patterns, given only a few cues. This style of education is a version of the traditional science education fundamental to normal science.

These three factors--consensus, pattern recognition, and education style--provide the Japanese with a strong basis for conducting normal science. With only these qualities, the Japanese would excel at the exploitation and application of existing theory but would be unlikely to accomplish the quantum jumps to new theories characteristic of extra-ordinary science. The cultural factors conducive to normal science do not encourage the type of divergent creativity necessary to make those types of theoretical breakthroughs.

> ... (The) education system in Japan does not leave much, if any, time for the development of independent thinking.... This characteristic, socially and historically based, may be restricting creativity in Japan, particularly creativity that would lead science and technology in new directions. [Ref. 16: p. 45]

The fourth factor strongly influencing the Japanese style of research, however, ensures that the Japanese will not stagnate at the level of normal science. This is the characteristic which Kikuchi calls flexibility. Flexibility, in this context, refers to the Japanese ability "... to absorb elements of foreign culture that are very different from our own--but with suitable modifications" [Ref. 16: p. 42]. Although not likely to initiate breakthroughs, their flexibility enables the Japanese to

rapidly assimilate new theories which are foreign generated. Once an externally produced idea finds access to the Japanese system, the system quickly attains in-phase oscillation as previously described. This consensus process, in conjunction with their proficiency at normal research, has allowed the Japanese to rapidly catch up with the United States in the field of solid-state electronics.

> ... "Catch-up" activities of this kind are very suited to Japanese engineers and scientists.... The Japanese are strong when they have a target to work on, whereas Western societies are stronger at finding new directions with a certain spirit of adventure. So the papers by Western authors show a preference for a way of thinking and analysis related to fundamental principles, and Japanese researchers concentrate more on sophisticated, detailed approaches to existing problems. [Ref. 16: pp. 43 and 45]

The Japanese scientific style provides an example of a scientific community internally skewed by cultural factors toward normal science. In addition, cultural characteristics determine the Japanese' receptivity to externally generated breakthroughs, followed by rapid group conversion and consensus reformulation. Thus, cultural factors have significantly contributed to Japan's successful competition in high technology areas.

D. THE PARENT SOCIETY

Cultural influences emanate not only through the internal composition of the scientific community, but also through the external pressures exerted by the parent

society. To some extent, the scientific community enjoys a degree of insulation from the larger society [Ref. 1: p. 119]. As noted in the previous chapter, scientists are the primary authorities judging the validity of each other's work. But the scientific community is dependent on the resources allocated by society and must function within the restraints imposed by that society. Resource allocations determine which scientific areas receive funds, equipment, and personnel. Cultural priorities, then, influence this distribution and the potential rate of scientific progress in different fields. These priorities, for instance, may emphasize military requirements at the expense of research applicable to civilian sectors. Culture may also determine the acceptability of a line of research. Thus, genetic engineering or the development of artificial intelligence may be suppressed as immoral or threatening to society. Cultures with a low tolerance for uncertainty may be less likely to accept the risks and costs associated with extraordinary science and divergent research efforts. Nobel prize winner Albert Szent-Gyorgyi describes the dilemma faced by the "Dionysian" scientist seeking to pursue divergent lines of research.

> Support mostly takes the form of grants, and the present methods of distributing grants unduly favors the Apollonian. Applying for a grant begins with writing a project. The Apollonian clearly sees the future lines of his research and has no difficulty writing a clear project. Not so the Dionysian, who knows only the

> direction in which he wants to go out into the unknown; he has no idea what he's going to find there and how he's going to find it. Defining the unknown or writing down the subconscious is a contradiction in absurdum. [Ref. 15: p. 124]

Szent-Gyorgyi solved his dilemma by preparing false project proposals to acquire funds for the research he actually intended to pursue. Cultural characteristics of the parent society, then, influence the direction of scientific research.

The parent society may also impose general conditions on the scientific community which are culturally motivated. In the Japanese example previously discussed, the cultural trait of flexibility assured an influx of new ideas to the system. Xenophobic cultures, on the other hand, may reject the infusion of foreign concepts or restrict the scientific community's access to foreign scientists. Pervasive cultural phobias may even affect the interaction between indigenous scientific communities. Thus capitalist industrial research requires a measure of secrecy to preserve the competitive edge. Similar restrictions are associated with military research and national security requirements. The extent of these restrictions and the areas of application will vary with the characteristics of the parent culture.

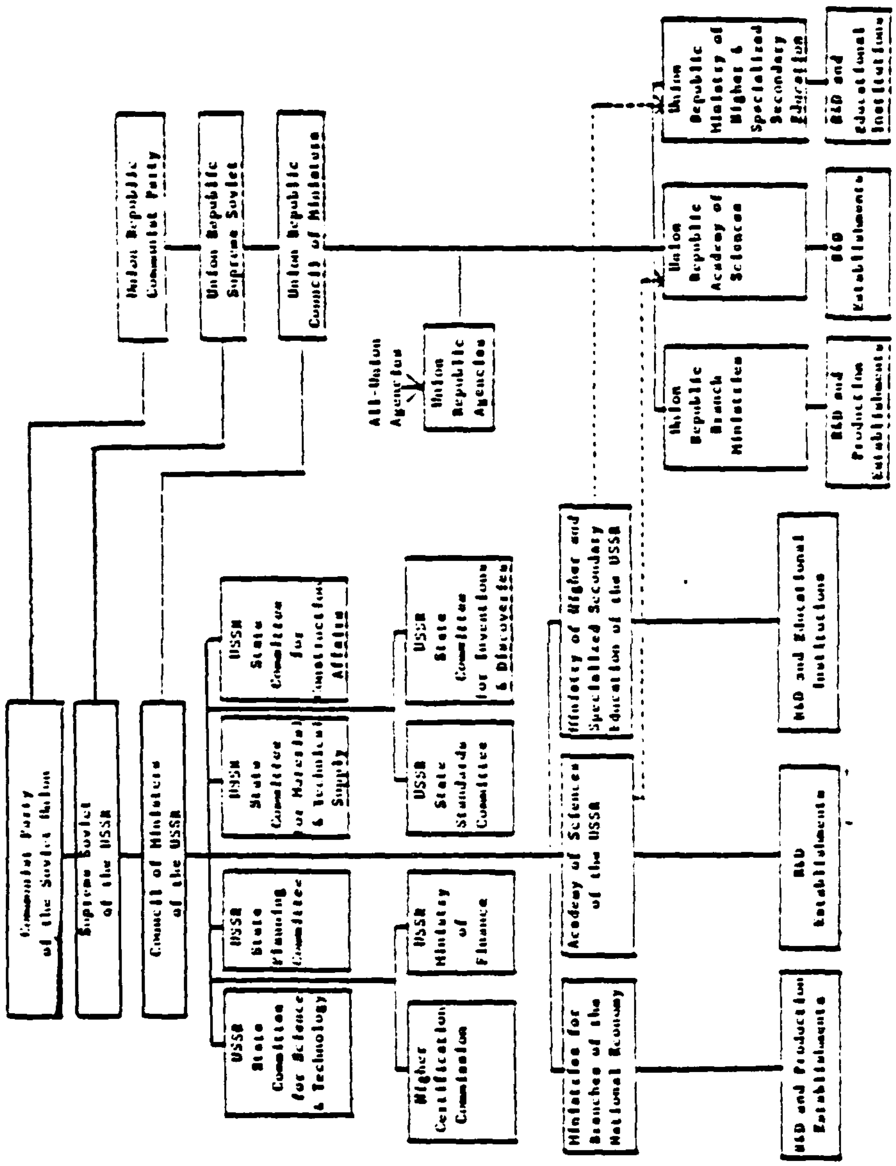
Scientific progress, then, is highly dependent on the cultural characteristics of the scientific community and the

parent society. These characteristics will influence the balance struck between convergent and divergent tendencies within the scientific community and the resultant level of tension propelling scientific progress. In addition, culture will influence the relationship between the scientific community and the parent society which also affects the rate and direction of scientific advancement. This permeability of the scientific process to cultural factors is a major determinant in a nation's scientific style. Thus, in analyzing the Soviet capability to pursue scientific research, the impact of Russian culture on the scientific community and the parent society will be considered.

IV. THE STRUCTURE OF SOVIET SCIENCE

Organizational structures manifest cultural characteristics. Organizations not only are shaped by the cultural milieu from which they emerge but, by the durability and inertia which they tend to acquire vis-a-vis the individual, organizational structures also serve to perpetuate and reinforce the characteristics which molded them. Organizational structure, then, is an important factor determining the impact of Russian culture on Soviet science.

Soviet science involves a multitude of organizations interacting hierarchically and bureaucratically. In general, broad policy guidelines for science are determined by the organs of the Communist Party--the Politburo, Secretariat, and Central Committee. These policies are then endorsed by the Supreme Soviet and administered by the Council of Ministers. State committees subordinate to the Council formulate the policy guidelines into plans, coordinating budget and resource allocations to the scientific communities dispersed within three major sectors--the academies of sciences, the industrial branch ministries, and the higher educational institutions. Figure 5 [Ref. 17: p. 19] illustrates the general relationships between these



Source: <u>Science Policy: USA/USSR; Science Policy in the Soviet Union</u>

Overall structure of the Soviet system of R&D planning and management

FIGURE 5

organizations. As indicated, this structure is mirrored in the republic governments with the republic Councils of Ministers, academies, and higher educational institutes subordinate to their USSR counterparts.

Ideally, this system is designed to integrate research and development into a centrally controlled plan maximizing national production. Various factors, however, have impeded this integration. In the mid-1960s, the Soviet Union considered structural revisions to improve the integration of science and technology into the national economic plan [Ref. 17: pp. 251-97]. In 1965 the State Committee for Science and Technology (GKNT) was formed to coordinate science policy in pursuit of structural solutions. While the formal relationships depicted in Figure 5 have not been altered, the nature of these relationships have changed over the past two decades as the GKNT, and other structural revisions, gained influence in the system. The structure of Soviet science continues to evolve as the Soviet Union attempts to optimize technological integration in the production cycle. These organizations, their current relationships, and their evolution will be discussed below.

A. THE COMMUNIST PARTY

Science policy is determined at the highest government and Party levels of the Soviet Union. The organizations at this level are the Politburo, Secretariat, and Central

Committee of the Communist Party, and the Supreme Soviet and Council of Ministers of the Soviet government. The relationship between the Party and government is complex; however, the authority of the Party, though informal, is preeminent.

> In the Soviet Union, there is a separation of policy formulation from policy execution. The former is the prerogative of the Communist Party while the latter is the responsibility of the government. This should not be understood to mean that the Party does not take part in the implementation and the government does not assist in planning. There are cross lines between the two--organizationally and through key persons holding dominant positions in both Party and government. [Ref. 18: p. 17]

The Politburo provides broad guidelines for the economy, science, and technology. The operation of the Politburo epitomizes several characteristics of the Soviet style of government--rule by committee, reliance on a strong overall consensus, unaminous pronouncements preceded by unpublicized internal debates, and gerontocracy. In addition to these characteristics, several members of the Politburo possess technocratic backgrounds. In 1979, nine of the thirteen full members had graduated from technical or scientific educational institutes. These included L. I. Brezhnev (metallurgy training at Dnepropetrovski), Yu. V. Andropov (Marine Transportation Institute), and the general secretary, K. U. Chernenko (Gomel Auto Highway Technical Institute) [Ref. 19: pp. 12-3]. In 1975, General Secretary Brezhnev delineated the Party's role in science policy

formulation in an address to the Academy of Sciences on its 250th birthday.

> We have no intention of dictating to you the details of research topics--that is a matter for the scientists themselves. But the basic directions of the development of science, the main tasks that life pose, will be determined jointly. [Ref. 17: p. 133]

The Party's influence in this joint determination is pervasive. The Secretariat of the Central Committee can intervene in the ministries and other agencies to ensure adherence to both ideological principles and approved research plans. Several departments within the Secretariat provide day-to-day operational coordination. These include the Departments of Science and Higher Educational Institutions, Defense Industry, Heavy Industry, Chemical Industry, and Planning and Finance. Party influence at the lower levels is exercised through the Party cells associated with each research institute. [Ref. 17: pp. 24-5; and Ref. 19: p. 12]

The Central Committee of the Communist Party exerts party influence through its control of personnel selection. Nominees to major positions, such as directors of important research institutes, leaders of sectors, and deans of universities, are screened and approved by the Central Committee. Through this mechanism, the Central Committee affects research institutes at the union, republic, and local levels. [Ref. 17: p. 25; Ref. 18: p. 20; and Ref. 19: p. 12]

Another Party organ influencing science policy is the Committee for State Security (KGB). The KGB exercises authority in four areas affecting scientific research by: 1) censorship of scientific publications; 2) having KGB representatives in all scientific organizations; 3) control of travel by Soviet scientists; and 4) control of travel by visiting scientists [Ref. 19: pp. 4 and 13]. Thus the Party influences Soviet science by determining basic policy, selecting key personnel for science related organizations, controlling science publications and access to foreign scientists, and permeating science organizations with Party representatives to ensure compliance with Party directives.

B. THE SOVIET GOVERNMENT

While the Party determines basic policy and oversees its implementation, the Soviet Government is formally charged with executing that policy. The highest government organ is the Supreme Soviet. The unwieldy size of the Soviet (1500 members) and the infrequency of its meetings (six to seven days a year) preclude an active role in policy formulation or execution. Instead, the Supreme Soviet serves to endorse and legitimize the policies of the Communist Party and their formulation into national plans by the Council of Ministers.

The Council of Ministers administers the Soviet ministries and other government agencies. The Council is composed of approximately 100 members including ministers,

chairmen of state committees, and the fifteen chairmen of the republic Councils of Ministers. Members of the Council are also members of the Party Central Committee [Ref. 17: pp. 24 and 28]. Control in the Council is centralized in its thirteen member Presidium. As with the Politburo, many of the members have technical backgrounds and four of the state committees associated with science and technology are represented on the Presidium [Ref. 17: p. 30; and Ref. 19: p. 14]. This level of participation in both the Presidium and Politburo led John Turkevich to comment that "... in no other country is science represented at such a high level in policy formulation" [Ref. 18: p. 22].

Directly subordinate to the Council of Ministers are the state committees, the all-union and union republic ministries, the republic Councils of Ministers, and the USSR Academy of Sciences. While science administration falls under the purview of the ministries, academy, and republic governments, the state committees provide services which cross ministerial and departmental lines. These services include planning, finance, and supply [Ref. 17: pp. 29 and 35]. Of the fourteen state committees, those primarily involved in science and technology are the State Committee for Science and Technology (GKNT), the State Planning Committee (Gosplan), the State Committee for Material and Technical Supply (Gossnab), the State Committee for

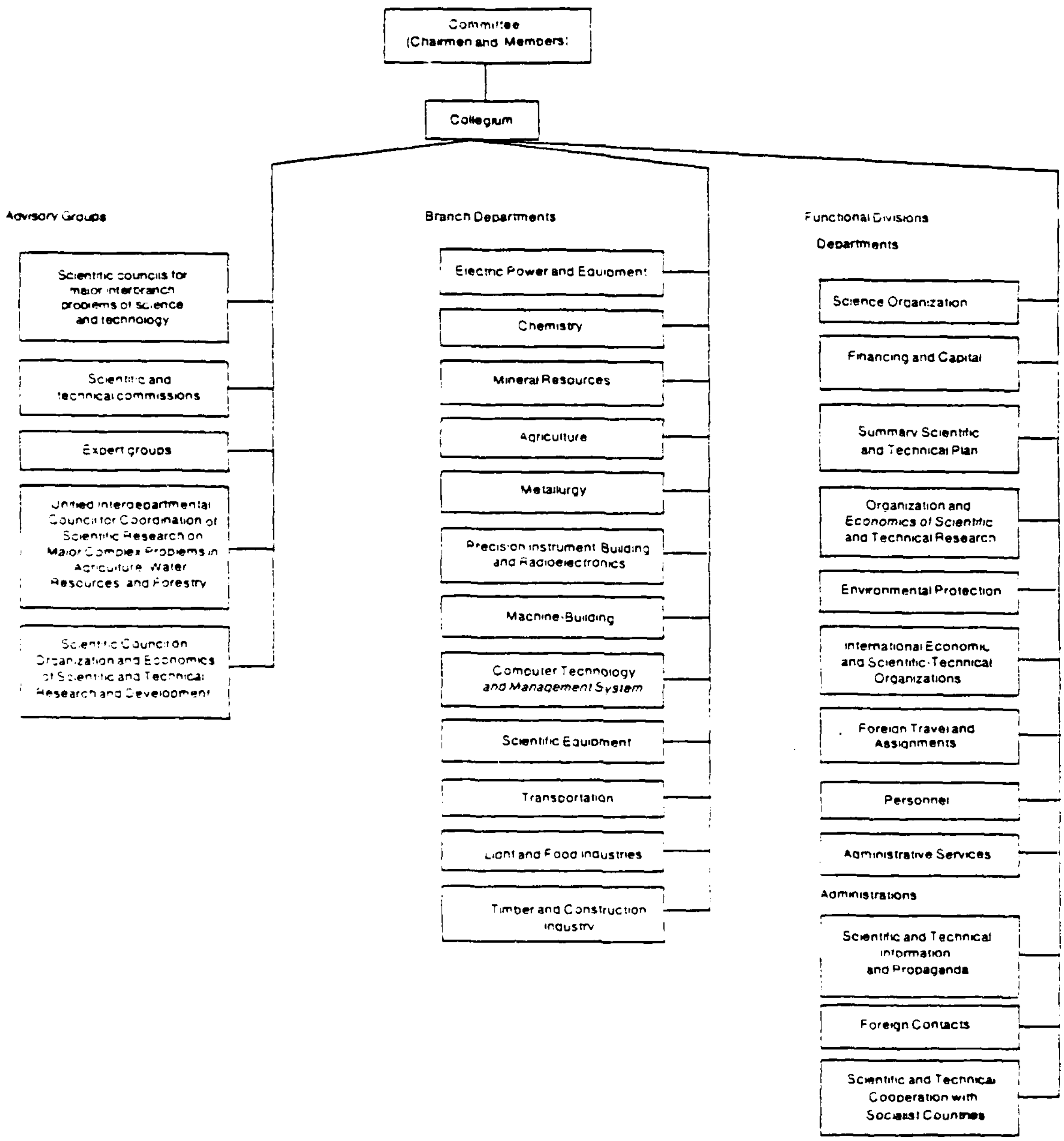
Construction Affairs (Gosstroy), the State Committee for Inventions and Discoveries (Goskomizobreteniya), the State Committee for Standards (Gosstandart), and the State Bank (Gosbank) [Ref. 17: pp. 29-30]. Of these, the State Committee for Science and Technology and the State Planning Committee exert the greatest influence on Soviet science and technology. The other committees respond to the directives provided by Gosplan. The State Committee for Material and Technical Supply provides supplies to the industries, academies, and universities. The State Committee for Construction Affairs coordinates the construction and renovation of research facilities as well as the introduction of technical innovations into construction practices. The State Committee for Standards introduces and monitors industrial standards of production. The increasing precision of these standards is one of the mechanisms intended to encourage technical innovation in production. The State Committee for Inventions and Discoveries issues author certificates and patents and disseminates information about inventions nationally [Ref. 17: pp. 43-45].

The State Committee for Science and Technology coordinates the science and technology activities of the other committees and government agencies. the GKNT was established in 1965 as part of the Soviet leadership's efforts to integrate science policy more closely with

national production designs. The GKNT had gradually assumed some of the traditional responsibilities of the USSR Academy of Sciences in determining national science policy. This was especially true in planning applied research, but the State Committee's authority over the science and technology components of the State Budget endows the GKNT with considerable influence in all facets of research [Ref. 18: pp. 45-6; and Ref. 20: p. 213]. The GKNT prepares inputs relating to science and technology for the annual and five-year State Plans for Development of the National Economy in coordination with Gosplan, the USSR Academy of Sciences, the Ministry of Finance, the USSR ministries, and the union republic Councils of Ministers [Ref. 17: pp. 93-4]. In addition to negotiating State Budget expenditures for the entire scientific community, the GKNT directly controls the allocation of approximately 30 percent of those expenditures to research performers involved in high priority science and technology research [Ref. 17: p. 95]. The GKNT, with Gosplan and the USSR Academy of Sciences, also compiles this list of 200 to 250 problems for inclusion in the five-year plans [Ref. 17: p. 114; and Ref. 18: p. 46]. Another important resource controlled by the GKNT is a two to three percent reserve of the annual budget allocation to science which the Committee can distribute to important research projects on short notice [Ref. 17: p. 99; and Ref. 19:

p. 17]. These budgetary controls provide the Committee with a powerful mechanism for influencing science policy.

The structure of the GKNT is shown in Figure 6 [Ref. 19: p. 18]. The Committee is relatively small with approximately 70 members on the full Committee and 16 members in the GKNT's executive body, the collegium. Approximately one-third of the Committee members are also members of the USSR Academy of Sciences or other academies [Ref. 17: pp. 37-8; and Ref. 19: p. 16]. The permanent staff of the Committee is only about 600, however, approximately forty to sixty scientific councils addressing various high priority problems provide the Committee with the voluntary assistance of some 5,500 persons including influential scientists, industrial managers, and research specialists [Ref. 17: p. 38; Ref. 18: p. 46; and Ref. 19: p. 16]. Only a few institutes are directly subordinate to the GKNT, and these are primarily concerned with information dissemination and science management rather than laboratory research. These institutes include the Institute of Technical Esthetics, the All-Union Scientific and Technical Information Center (VNTIT), the Institute of Systems Research, and the All-Union Institute of Scientific and Technical Information (VINITI). The latter institutes are jointly managed by the GKNT and the USSR Academy of Sciences [Ref. 18: p. 46; and Ref. 19: pp. 17 and 74]. VINITI is of special importance,



Source: Science and Technology in the Soviet Union: A Profile

Structure of the State Committee for Sciences and Technology (GKNT)

FIGURE 6

as its function is to acquire and disseminate foreign technology publications.

The State Committee for Science and Technology, then, coordinates the national science and technology efforts across academy, ministerial, and educational jurisdictions. To achieve this coordination, the GKNT negotiates and formulates the science expenditure portions of the annual State Budget and establishes science and technology goals for the annual, five-year, and long range plans. With these powers, the GKNT can significantly influence the direction of Soviet science policy.

The other state committee significantly affecting science policy is the State Planning Committee (Gosplan). Gosplan coordinates the inputs of other state committees, ministries, republic governments, and government agencies into the final annual budget and five-year and long range plans. These plans are submitted to the Council of Ministers, Supreme Soviet, and Politburo for legislative approval. Gosplan then translates the general policy directives provided by the Party and Council of Ministers into allocations of material and financial resources. This requires Gosplan to balance the needs of the economy and national defense while preserving the intent of communist ideology. Thus,

> in addition to five-yearly plans, the Gosplan formulates both long-range and yearly plans, intended to assure a proportional development of the national economy, continued growth, and increased efficiency of the

> national industry in order to increase the standard of living and strengthen national defense. Gosplan attempts to base plans on contemporary accomplishments and progress in science and technology on the results of scientific investigations of the economic and social problems of communism and a comprehensive study of social demands. [Ref. 18: p. 27]

Science expenditures, overall wages, material and financial outlays for research projects, and construction and renovation investments are provided in the national annual plan. [Ref. 17: p. 93]

C. CENTRAL PLANNING

Formulation of the annual budget and five-year plans involves the full hierarchy of organizations. The Politburo and Council of Ministers issue general directives for the plan. The directives are then developed into more detailed and comprehensive objectives by the GKNT, USSR Academy of Sciences, and Gosplan. Then,

> preliminary plan assignments ... are transmitted down the respective hierarchies--Academy, ministry, republic--to the performing organizations. ...(These) establishments prepare draft plans which are routed up through the hierarchy, aggregated at each stage. They are considered and reconciled (with bargaining) by the triad of central management organs (GKNT, Academy, and Gosplan).... Plans are then approved by the Council of Ministers and the Politburo, approved by the Supreme Soviet, and transmitted down the administrative ladder with formal and official plan assignments specified at each level. [Ref. 17: p. 130]

Central planning carries powerful implications for Soviet science policy, though there is ample room for bureaucratic interpretation and misdirection in formulating and exercising the national plans. Central planning

encourages conservatism both in the directives issued from the top governmental organs and in the plan proposals submitted by the performing establishments.

> The Soviet system is particularly incremental. The tendency to plan from the achieved level reflects an "add on" approach to design that encourages scaling up existing processes rather than developing new ones and sees continuity as the best guarantee of meeting planned output goals. [Ref. 17: p. 316]

In attempting to develop long range comprehensive plans for science and technology, the USSR Academy of Sciences and the GKNT in 1973 began developing a 15 year plan, "Comprehensive Program of Science and Technology Progress and Its Social and Economic Consequences for 1976-1990." This program is still under development and has not been approved by the Party; however, a major aspect of the program is that the projects addressed are premised on scientific and technological achievements [Ref. 17: p. 271]. This has caused consternation among some Soviet planners that "... (the) conservative approach to building the future entirely on the accomplishments of today, no matter how high, will only lead to 'planned obsolescence'." [Ref. 17: p. 272]

Once approved, the annual plan has the force of law, thereby encouraging conservatism at the performer level as well. The incentives of the system are such that the performer will submit proposals which he can be sure to fulfill.

> The work of both individuals and institutions is evaluated primarily in terms of their formal fulfillment of the thematic and financial plans, not on the basis of the real value of their S&T achievements. There is a strong tendency therefore to propose "safe" and relatively minor themes, whose parameters are fairly well known and results more certain. [Ref. 17: p. 237]

After the plan is promulgated, there is little flexibility to adjust to the unforeseen pitfalls and opportunities of scientific research.

> Only rarely are superior bodies inclined to permit alterations in annual plan targets. They discourage the raising and reducing of targets because such actions can reverberate and disrupt the economy. The plan is thus ambitious and inflexible: this consideration alone fosters conservatism and works against unpredictable activities like R&D. [Ref. 17: p. 176]

The budgetary system incorporated in the annual plan also affects Soviet science. Research performers receive financing either directly from the State Budget or from contractual agreements with industrial or other agencies. funds received from contractual agreements account for approximately fifty percent of science expenditures, and primarily support applied research activities. The State Budget grants are those funds from the national plan negotiated by the GKNT for science expenditures. These funds account for the other fifty percent of science expenditures and go to basic research activities. Approximately thirty percent of the State Budget grants for research and development is controlled by the GKNT for allocation to research performers based on their participation in the 200

to 250 basic problem areas delineated in the national plans. Seventy percent of the State Budget funds for science expenditures are distributed directly to the ministries, the USSR Academy of Sciences, and other research performers as block grants, to be used and further distributed at their discretion [Ref. 17: pp. 94-5]. This discretion is not total, however, as the national plan not only lists 200 to 250 basic science and technology problems of high national priority, but also fundamental research problems to be addressed by the natural and social sciences.

> The R&D targets are divided for national planning into fundamental problems of chemistry, physics, mathematics, biology, geology, social sciences and humanities, branch problems in improvement of production, territorial problems in the development of production forces,and inter-regional and inter-branch problems. [Ref. 18: p. 29]

Overall, central planning may account for up to fifty percent of research and development project selections, ministerial planning for approximately thirty percent, and local planning for the remainder. [Ref. 17: pp. 116 and 119]

The implications of the Soviet budget process are twofold. Block funding provides the institution with a stable income which permits long term planning and research continuity. On the other hand, this stability reduces organizational dynamics.

> Conservative tendencies stifle creativity and change. The inertia of institutions and projects is hard to break. R&D facilities and programs can go for years without producing signficant results. [Ref. 17: p. 306]

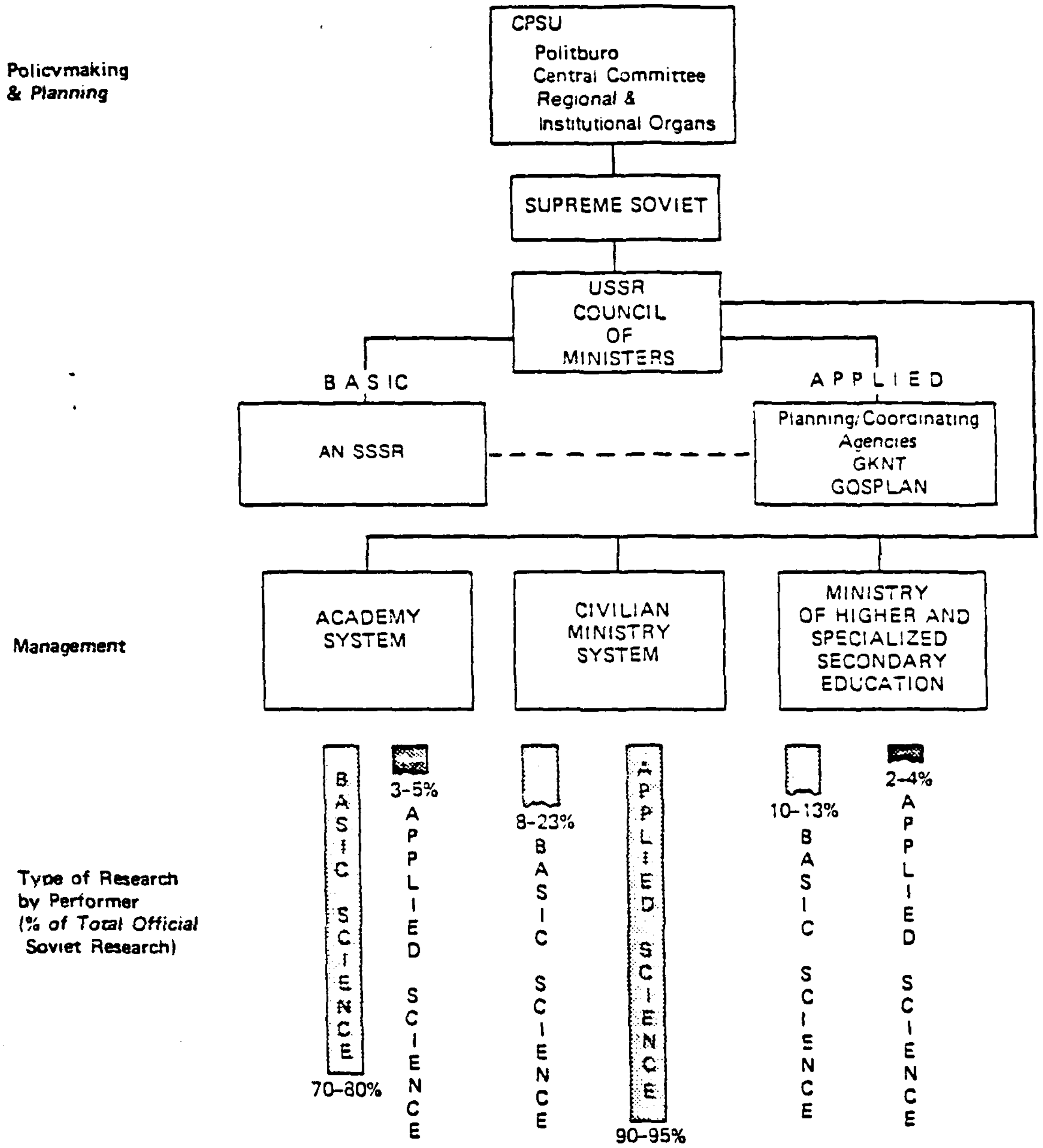
The resulting rigidity of established science institutes also obstructs the incorporation of new projects and fields of research. In many instances, new research institutes are established to pursue projects and fields of interest to top Party and government organizations rather than charging established institutes with their responsibility.

> In practice, it is easier to create a new R&D facility than to transform an old one. This option, however, which has been frequently used, is less viable today given the constraints on resources and need for intensive development of both science and technology. [Ref. 17: p. 266]

Central planning and budgetary methods have the potential advantage of permitting long term, comprehensive science and technology development. The current Soviet system, however, encourages incremental scientific research and bureaucratic inertia.

D. RESEARCH PERFORMERS

There are three broad categories of research performers in Soviet science. These are the academies of sciences, the industrial branch ministries, and the higher educational institutions (universities and VUZy). The academies and educational institutes conduct the majority of basic research activities while industrial institutes concentrate on applied research. This breakdown is shown in Figure 7 [Ref. 19: p. 10]. The GKNT and Gosplan formulate plans for applied research and therefore significantly affect



Source: Science and Technology in the Soviet Union: A Profile

Soviet institutional relationships and R&D by performer

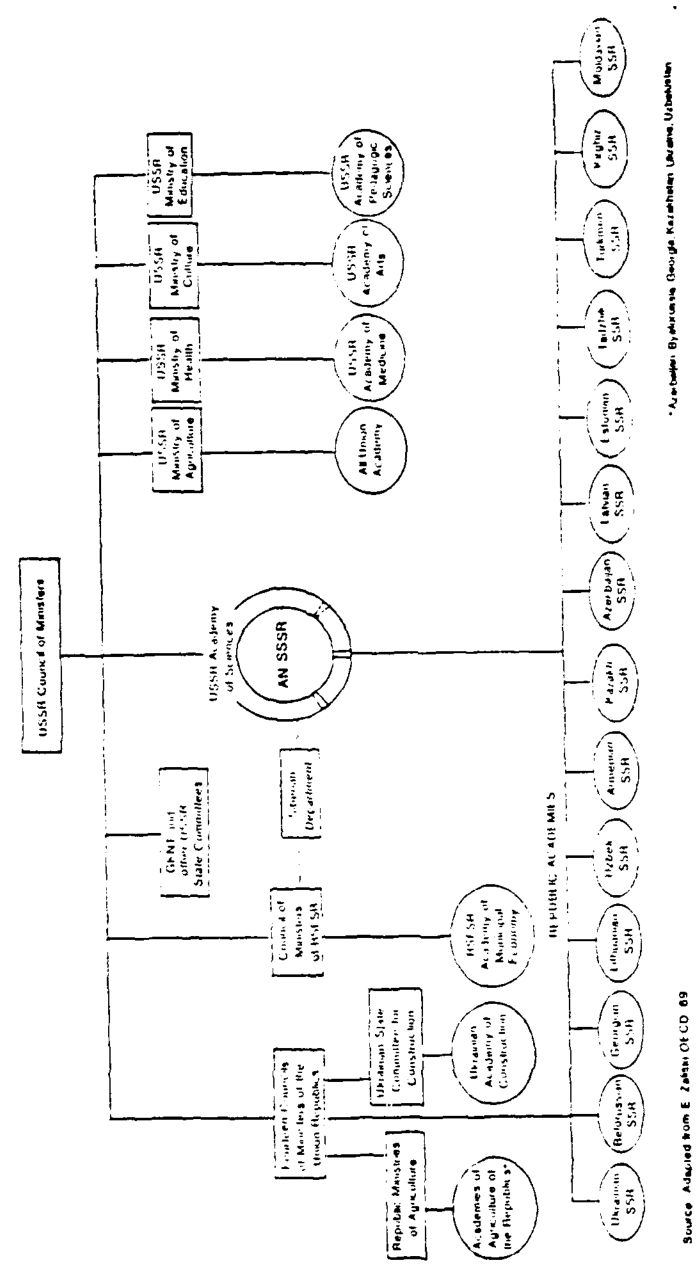
FIGURE 7

industrial and educational research activities. The USSR Academy of Sciences has somewhat greater autonomy and, in cooperation with GKNT and Gosplan, has primary responsibility for directing fundamental research based on Party directives.

1. The Academies of Sciences

There is a network of academies of sciences in the Soviet Union, of which the USSR Academy of Sciences (AN SSR) is the senior and most prestigious. These academies fall into three categories--the USSR Academy of Sciences, the republic academies, and specialized academies. The USSR Academy of Sciences is subordinate to the USSR Council of Ministers, while the republic and specialized academies are subordinate to both their respective republic Councils of Ministers or ministries and the USSR Academy. For these academies, the appropriate Council of Ministers or ministry provides funding and administrative guidance and the USSR Academy coordinates research planning. The Presidium of the USSR Academy approves the final annual plan prepared by each research institute [Ref. 19: p. 25]. These relationships are shown in Figure 8 [Ref. 19: p. 31].

Overall, the academies employ approximately nine percent of the Soviet scientific workers and receive eight percent of all science expenditures [Ref. 17: p. 46]. Of these expenditures, approximately ninety-two percent is from



Source: <u>Science and Technology in the Soviet Union: A Profile</u>

Network of Soviet academies

FIGURE 8

State Budget grants and eight percent from contractual agreements [Ref. 19: p. 68]. The strengths of the various academies in terms of membership and the numbers of scientific establishments controlled by each, are shown in Table V [Ref. 19: p. 32]. In addition to being significantly smaller, the republic academies are generally more specialized and industrially oriented than the USSR Academy [Ref. 17: p. 49].

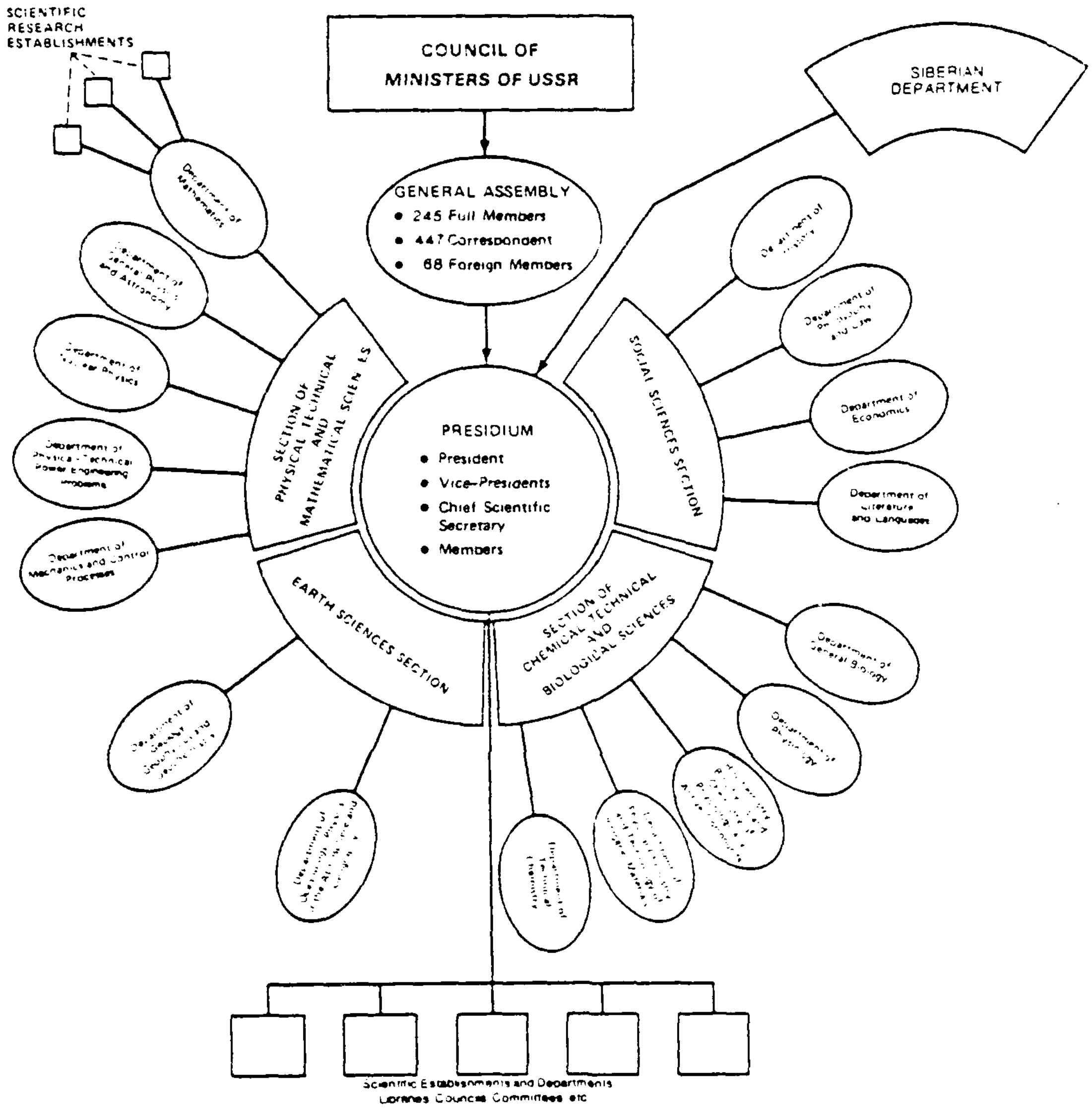
The USSR Academy of Science is both the nucleus of this network and the organizational pattern for the republic academies. Its organization is shown in Figure 9 [Ref. 19: p. 33]. The General Assembly, composed of 245 full members, 447 corresponding members, and 68 foreign members, meets only twice a year for several days. Despite this restriction, the General Assembly retains considerable power in its authority to elect the president, vice president, and members of the Academy Presidium as well as new full and corresponding members of the General Assembly by secret ballot [Ref. 19: pp. 32-3]. The tradition of election by secret ballot has enabled the USSR Academy to preserve some autonomy from Party influence, even to the extent of refusing membership to many candidates proposed by the Party. However, while the first four presidents of the Academy were not Party members, the election of Party members as the last two presidents may indicate greater Party influence in the Academy [Ref. 19: p. 35-6].

TABLE V

Network of Soviet Academies (December 1975)

	Year Founded	Number of Active Members and Corespond-ing Members	Number of Scientific Establish-ments
USSR Academy of Sciences	1724	678	246
Union-Republic Academies			
Ukrainian SSR	1919	282	76
Belorussian SSR	1928	131	33
Georgian SSR	1941	109	40
Lithuanian SSR	1941	39	12
Uzbek SSR	1943	96	31
Armenian SSR	1943	90	31
Kazakh SSR	1945	132	33
Azerbaijan SSR	1945	90	32
Latvian SSR	1946	52	16
Estonian SSR	1946	44	16
Tadzhik SSR	1951	42	19
Turkmen SSR	1951	49	16
Kirghiz SSR	1954	44	19
Moldavian SSR	1961	37	19
Total		1237	393
Specialized Academies			
All-Union Academy of Agricultural Sciences Imeni Lenin	1929	211	170
RSFSR Academy of Municipal Economics	1931	---	5
USSR Academy of Medical Sciences	1944	271	40
USSR Academy of Art	1947	130	5
USSR Academy of Pedagogical Sciences	1966	131	14
Total		743	234

Source: Science and Technology in the Soviet Union: A Profile



Source: <u>Science and Technology in the Soviet Union: A Profile</u>

The USSR Academy of Sciences

FIGURE 9

The Academy's general policies historically have been significantly influenced by Party directives. In the late twenties, the Party ensured the election of Party members, particularly engineers, into the Academy to shift the Academy's focus from basic to applied science. The emphasis on applied research continued into the late 1950s, when Krushchev supported debates between the scientists and engineers over the Academy's role. These debates culminated in 1961, when over forty percent of the Academy's science establishments were transferred to control by industrial ministries [Ref. 18: p. 47]. The Academy's loss of influence in applied research, however, was compensated with increased authority over all basic research in Academy and non-Academy institutes, higher educational institutes, and the ministries [Ref. 19: p. 29]. This return to a greater emphasis on basic research by the Academy, however, did not imply greater freedom from the Party.

> While the boundaries of intellectual freedom to pursue research have been extended in the post-Stalin period, science has not been freed from political influence. Soviet authorities still make demands upon the scientists, although frequently different ones than they made in the past. Controls over scientists have not really been relaxed, but the goals of such controls have been redefined in accord with changing official perceptions of national needs. Today it is the problems of a more sophisticated society and industrial order that Soviet scientists and engineers are under pressure to address and solve. [Ref. 17: p. 4]

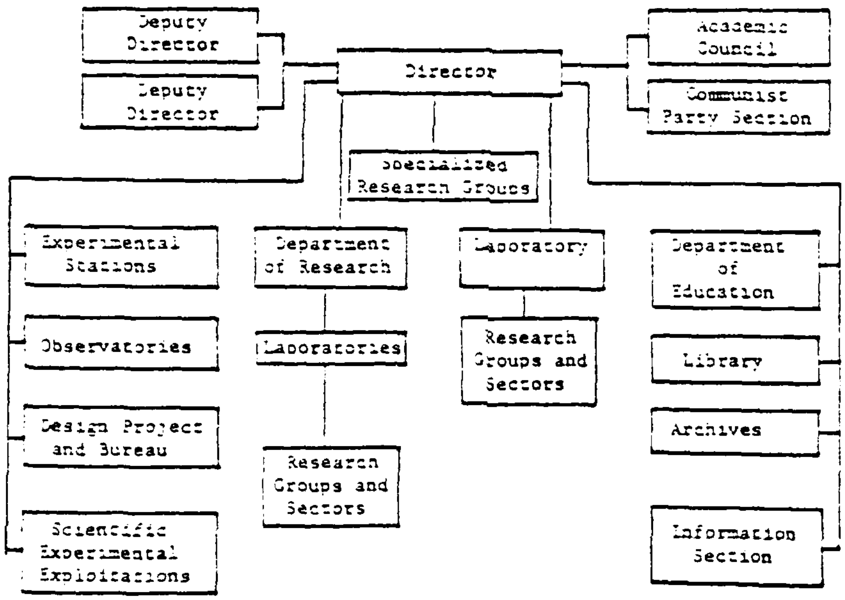
The academies control institutes, laboratories, experimental stations, observatories, libraries, and museums

[Ref. 18: p. 36]. Of these, the research institute is the primary performer. Institutes vary in size from forty to several thousand scientists and engineers, as well as in their degree of specialization [Ref. 17: p. 65]. A typical organization of an Academy research institute is shown in Figure 10 [Ref. 17: p. 66]. The research director exercises considerable control over the institute. Directors are elected by secret ballot by the Academy's General Assembly. They are formally elected for four year terms but in practice may serve indefinitely. The director's power lies in his autnority over the organization of research work, selection of projects and personnel, and distribution of block grants and contractual finances [Ref. 19: p. 34]. The director also may modify thcse aspects of construction projects not specified in the annual plan [Ref. 18: p. 36].

The Academic Council (or Learned Council) assists the director. It is composed of the director, deputy directors of scientific affairs, the scientific secretary, the heads of departments and sections of the institute, Party representatives, trade union representatives, and eminent scientists. The Council advises the director on matters of planning and organization as well as on science policy [Ref. 19: p. 34].

2. The Industrial Branch Ministries

The second category of research performer is the industrial branch ministry. There are three kinds of



Source: Science Policy: USA/USSR; Science Policy in the Soviet Union

Organizational structure of a research institute
of the USSR Academy of Sciences

FIGURE 10

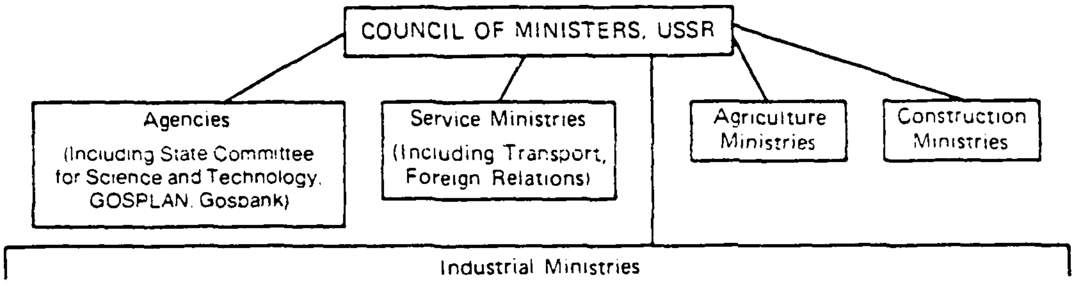
ministries in the Soviet Union. The first, all-union ministries, are responsible for priority national functions which transcend republic jurisdiction; these ministries directly administer subordinate activities. The second, union-republic ministries, generally coordinate intra-republic functions through each republic's counterpart ministry. The third, republic ministries, are subordinate only to their appropriate republic Councils of Ministers [Ref. 17: p. 29]. Figure 11 shows the all-union and union-republic industrial ministries [Ref. 19: p. 46].

Industrial ministries control two kinds of research and development organizations--the branch institute and the industrial enterprise. The branch institute is similar to the academy research institute. Figure 12 [Ref. 19: p. 50] shows the organization of a typical branch institute. As in the academy institute, the director is a powerful figure.

> Appointed by the minister, the director organizes the institute's work, formulates project and personnel training plans, arranges financial and technical procurement, oversees publication work, and establishes and changes pay scales. [Ref. 19: p. 47]

Unlike the academy institutes, branch institute directors are generally not scientists and are often less qualified to manage research activities [Ref. 17: p. 179; and Ref. 19: p. 47].

The second major kind of research organization is the industrial enterprise. The enterprise is primarily



Industrial Ministries
(Excludes Republic Ministries)

Civilian

All-Union

Chemical Industry
Chemical and Petroleum Machine Building
Construction, Highway and Municipal Machine Building
Electric Equipment Industry
Gas Industry
Heavy, Power and Transport Machine Building
Machine Building for Light and Food Industry and for Household Appliances
Machine Tool and Tool Building Industry
Medical Industry
Motor Vehicle Industry
Petroleum Industry
Precision Instruments, Automation Equipment and Control System
Tractor and Agriculture Machine Building

Union-Republic

Coal Industry
Construction Materials Industry
Ferrous Metallurgy
Fishing Industry
Food Industry
Geology
Light Industry
Meat and Dairy Industry
Nonferrous Metallurgy
Petroleum Refining and Petrochemical Industry
Power and Electrification
Pulp and Paper Industry
Timber and Wood Processing Industry

Defense

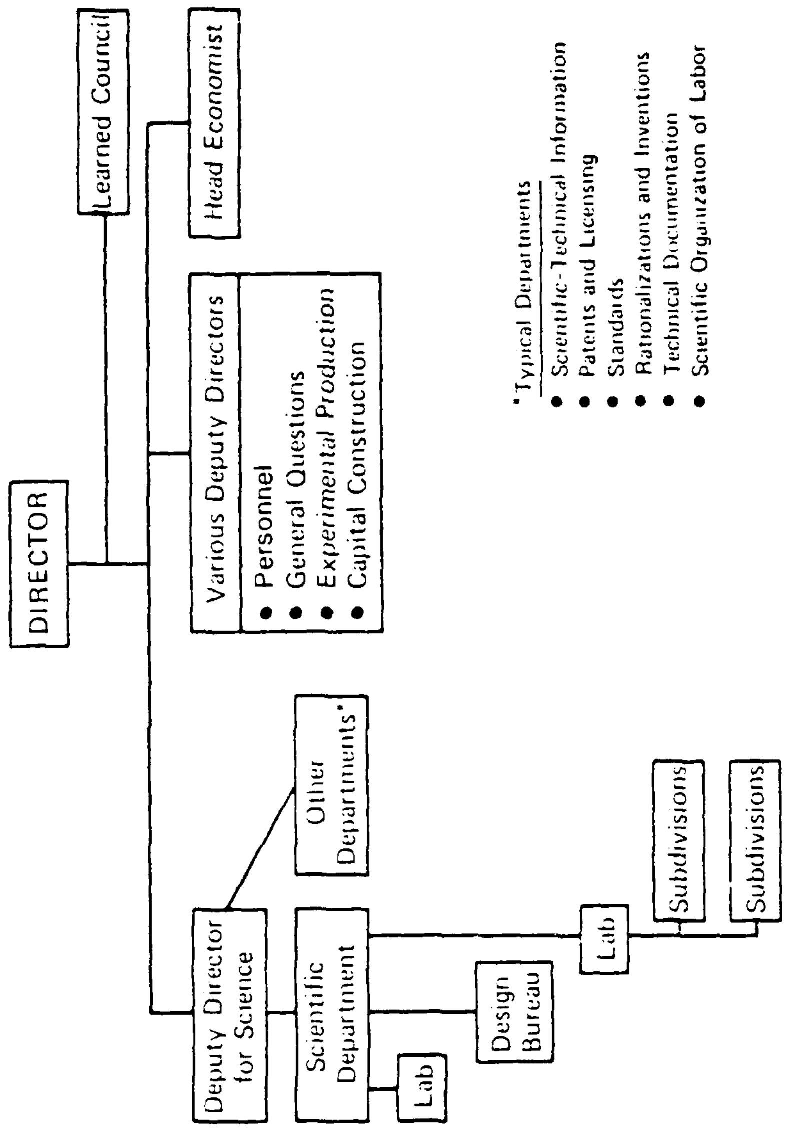
All-Union

Aircraft Industry
Defense Industry
Electronics Industry
General Machine Building
Machine Building
Medium Machine Building
Radio Industry
Shipbuilding

Source: Science and Technology in the Soviet Union: A Profile

The all-union and union republic industrial ministries

FIGURE 11



Source: Science and Technology in the Soviet Union: A Profile

Branch R&D organization

FIGURE 12

concerned with production but may have its own research and development facilities. However, "... for the most part enterprises only adopt and expand technology originating elsewhere and supply technical support to the production unit" [Ref. 19: p. 45]. To improve the incorporation of new technology into production processes, the USSR Council of Ministers in 1973 decreed that enterprises and branch institutes be merged into associations. Associations, in which research is secondary to production, are production associations (PO) while those in which research is primary are scientific production associations (NPO). This restructuring is still being implemented [Ref. 17: p. 59; and Ref. 19: pp. 50-1].

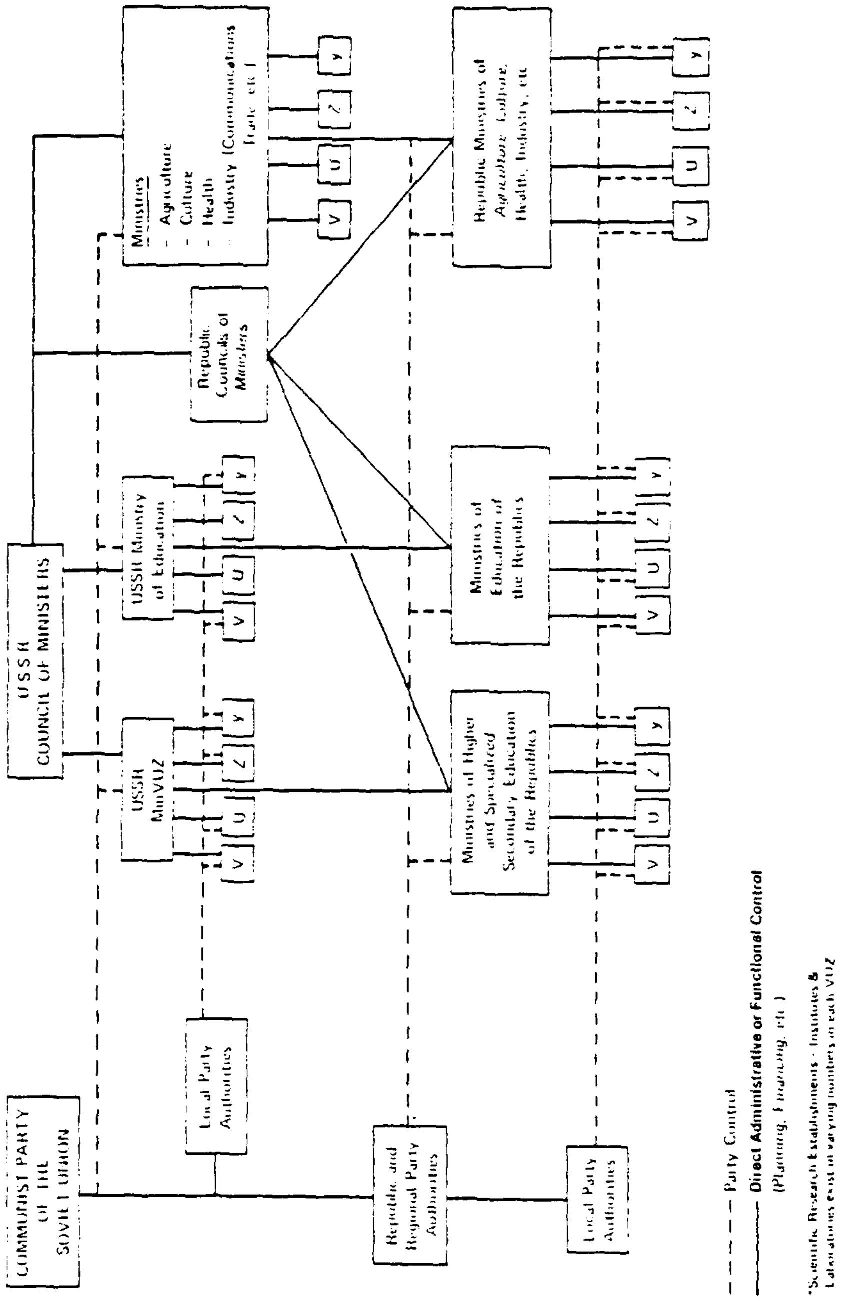
Industrial research and development receives the major share of national science finance and manpower allocations. The branch institutes employ approximately fifty-eight percent of the scientific workers and receive eighty percent of the total science expenditures. Of these funds, twenty to twenty-five percent are received from State Budget grants while seventy-five to eighty percent are from ministerial or contractual sources. The enterprises employ three percent of the scientific workers and receive two percent of the science funds. Fifteen percent of these funds are from State Budget grants and the remainder from contracts and ministerial sources [Ref. 17: pp. 46 and 95].

Overall, civilian ministries control 3,620 research institutes [Ref. 19: p. 11].

3. Higher Educational Institutes

The third major category of research performer in the Soviet Union is the higher educational institute. Higher educational institutes control 859 research institutions [Ref. 19: p. 11]. The Ministry of Higher and Specialized Education (MinVUZ) administers research conducted in universities and in non-university higher educational institutes (VUZy) such as specialized schools and polytechnic institutions. Only one-third of the VUZy are directly subordinate to MinVUZ, however, with the remainder subordinate to various specialized ministries. This relationship is shown in Figure 13 [Ref. 19: p. 57]. Those directly subordinate to MinVUZ conduct ninety percent of total VUZy research while VUZy controlled by the Ministries of Agriculture and Health conduct ten percent [Ref. 19: p. 55]. The research institutes associated with the Soviet Union's 65 universities concentrate on fundamental research. Those associated with the more specialized VUZy are primarily concerned with applied research [Ref. 19: pp. 53-4].

Unlike the United States, research and education are not closely associated. After the Revolution, the Soviet government chose to separate research and educational



Source: Science and Technology in the Soviet Union: A Profile

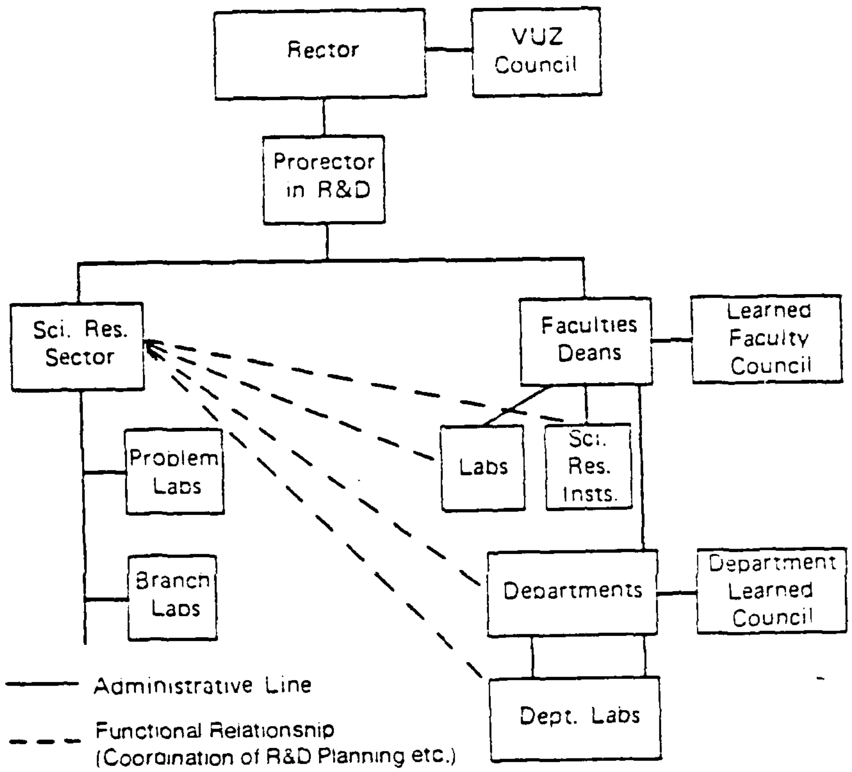
Administrative structure of higher educational institution

FIGURE 13

functions. In the mid-1950s, however, the Party decided to reincorporate research into the educational system.

Research participation by educational facilities is still increasing, with an estimated sixty percent of the VUZy daytime students currently assisting in research activities [Ref. 17: p. 60]. The USSR Academy also assumed an increasing association with higher educational institutes. The Academy not only plans basic research conducted at the universities and VUZy, but Academy scientists lecture and write textbooks for educational institutes. In addition, Academy research facilities may be made available to VUZy researchers and students [Ref. 19: p. 56]. The University of Novosibirsk, created in 1959, is a unique fusion of Academy and MinVUZ efforts to train scientists. The Academy selects the best students from the country to participate in this strongly research oriented institution. The professors are all researchers attached to the USSR Academy's Siberian Department and the students, by their third year, are also conducting research in an Academy institute. This university represents the highest integration of education and research [Ref. 18: p. 54; and Ref. 19: pp. 41-2].

The organization of a more typical VUZy research facility is shown in Figure 14 [Ref. 19: p. 58]. The rector is responsible for the formulation and implementation of the



Source: <u>Science and Technology in the Soviet Union: A Profile</u>

Organization and administration of research at higher educational institutions

FIGURE 14

research plan while the prorector administers research activities [Ref. 19: p. 58]. Overall, higher educational institutes employ twenty-eight percent of the nation's scientific workers and receive nine percent of the science expenditures. Eighty percent of these funds are from contract sources and twenty percent from State Budget grants [Ref. 17: p. 46; and Ref. 19: p. 70].

E. MILITARY RESEARCH AND DEVELOPMENT

Military related research efforts are assumed to dominate Soviet science and technology, though the extent is unknown. Unspecified military research expenditures are subsumed in the overall national science budget; however, estimates range from forty to eighty percent of research and development resources being devoted to military requirements [Ref. 18: p. 189; and Ref. 19: p. 22]. The nature of the interaction between the military and research and development communities is, therefore, an important element in the structure of Soviet science.

Military research policy is determined by the Party's Politburo. Structurally, the organizations involved in military research and development parallel and interface with the civilian organizations previously discussed. The Defense Council, a subcommittee within the Politburo advised by top military officials, "... probably reviews and makes recommendations regarding such major defense matters as the

defense budget, major weapons programs, and major shifts in military doctrine, which ... would be likely to come before the full Politburo for final decision" [Ref. 21: p. 46]. The Party Secretariat has four departments involved in military policy determination--the Departments of Defense Industry, Machine Construction, Administrative Organs, and the Main Political Administration of the Soviet Army and Navy (MPA). Three of these departments are associated with military research. Members of the MPA serve at military research institutes to administer political education and monitor morale. The Departments of Defense Industry and Machine Construction jointly supervise those governmental ministries primarily associated with defense industry [Ref. 21: pp. 48-9].

In the Soviet government, the Military-Industrial Commission (VPK), subordinate to the USSR Council of Ministers, is the highest organization coordinating military research and development.

> The chairman of the VPK, who is a member of the Council Presidium, integrates military production with R&D policies, establishes priorities and monitors their implementation, and coordinates military production with economic planning. [Ref. 19: p. 20]

In cooperation with Gosplan, VPK balances the requirements of the Ministry of Defense with the production capacities of the various defense related industrial ministries for inclusion in the annual and five-year plans [Ref. 21: p. 176].

While apparently not involved in this formulation of defense production inputs to national plans, David Holloway speculates that the GKNT alerts the military to civilian research with potential defense application [Ref. 18: pp. 208-9]. The GKNT also provides the military with foreign technology information through the services of VINITI [Ref. 19: p. 22].

There are eight ministries primarily engaged in defense production. These ministries--Defense Industry, Aviation Industry, Shipbuilding Industry, Electronics Industry, General Machine Building, Medium Machine Building, and Machine Building--and their defense products, are listed in Table VI [Ref. 21: p. 21]. These are not the only industries involved in military production nor do they produce armaments exclusively. Other ministries involved in military production, to a lesser extent, are those of Instrument Manufacture, Tractor and Agriculture Machinery Building, Chemical Industry, and Automobile Industry. The military services maintain close liaison with the defense industrial ministries through their weapons development directorate representatives. These military officers represent defense interests at ministry design bureaus and production plants. They are empowered to enforce precise technical specifications in research, product development, and application and to refuse substandard products [Ref. 1?:

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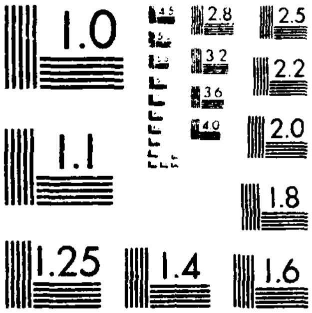

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

TABLE VI

The Defense Industrial Ministries and Their Products

Ministry	Product
Ministry of Defense Industry	Artillery, tanks, armored vehicles, small arms, fuses, primers, propellants, explosives, and possibly tactical guided missiles
Ministry of Aviation Industry	Aircraft, aircraft parts, and probably aerodynamic missiles
Ministry of Shipbuilding Industry	Naval vessels of all types
Ministry of Electronics Industry	Electronic components and parts (subassemblies, not finished equipment)
Ministry of Radio Industry	Electronic systems including radio and communications equipment, radar, and computers
Ministry of General Machine Building	Strategic ballistic missile and space vehicles
Ministry of Medium Machine Building	Nuclear devices and warheads
Ministry of Machine Building	Possibly some portion of ballistic missiles and space vehicles

Source: The Military in Contemporary Soviet Policies

p. 22; and Ref. 21: pp. 176, 131-2, and 186]. Quality standards for military items are higher than for civilian products [Ref. 18: p. 21].

The research institutes of defense industry ministries perform approximately ninety percent of military related applied research [Ref. 19: p. 21]. For basic research of potential military value, the military relies on the research efforts of the academies and higher educational institutes as well as on "invisible institutes"--secret military facilities not officially listed, which conduct both basic and applied research. The academies conduct some basic research for the military on a contractual basis [Ref. 19: p. 20]. In addition, however, the USSR Academy was charged in 1963 with responsibility to advise the military of potential technological applications of fundamental research [Ref. 18: p. 201]. The Academy's importance to defense has increased as military technology has become more sensitive to basic research developments.

> Before the Second World War it was, as a rule, the applied and technical sciences that influenced the development of weapons; but now basic research is coming to have a direct and immediate impact.... All scientific research is relevant to defense: "now it is impossible to name with firm conviction any branch of natural science which would be neutral or unnecessary for the development of military affairs. Any branch of natural sciences either already takes part, or can potentially be used in (military affairs)." [Ref. 18: p. 191].

Military industrial processes differ from civilian production in several aspects. Military production management is more highly structured, and utilizes sophisticated systems planning and management techniques similar to those used in American aerospace and defense industries. This program planning and financing often employs zero-based budgeting and a programmed-goals approach. Such a system facilitates the introduction of new ideas and projects and the termination of unproductive projects. This contrasts with the institutional inertia associated with block funding in the civilian sector [Ref. 17: pp. 97 and 321]. Another difference lies in the qualification of the institute directors to manage research and development. Unlike the civilian sector, where directors are often unqualified,

> in the defense-related sectors, such as the machine-tool and instrument making, radio, and electrical equipment industries, R&D management is qualified, experienced, and forceful. [Ref. 17: p. 179].

Military research also enjoys greater latitude in pursuing parallel lines of research. The Soviet philosophy views duplication and competition as wasting resources and inherent deficiencies of capitalism. Central planning is intended to eliminate this waste. Competition and duplication are tolerated to a greater degree in the military, however, due to the complexities and uncertainties of military technology and in light of the urgent military competition with the United States [Ref. 17: pp. 5 and 134].

Another aspect of the military sector is the greater restriction on communication among scientists.

> Pervasive secrecy does not generally permit access to Western scientists or the publication of research results in open literature. In addition, compartmentalization, conservatism, and a propensity for avoiding personal risks seem to be characteristic of military research in the U.S.S.R. [Ref. 19: p. 22]

Secrecy in the military sector has the additional effect of attracting lower quality personnel. "The secrecy which prevails in the defense sector makes it easier to gain higher degrees, and so qualifications are not necessarily a good indication of quality" [Ref. 18: p. 198]. Offsetting these restrictions on communication is the greater access which military research facilities have to foreign technical publications and VINITI services.

The secrecy associated with military research results in a one-way flow of information from the civilian sector. While the Academy and GKNT are responsible for tracking civilian research for potential military application, there is no reciprocation from the military sector.

> Nor has there been any substantial spin-off from these national security and high technology related projects in terms of civilian applications to national needs and improvements in the quality of life. [Ref. 17: p. 12]

In addition, military research receives priority in terms of financial, material, and human resources. Military research institutes offer higher wages and benefits to scientists and engineers. These institutes can also acquire laboratory

equipment in critical supply [Ref. 17: p. 103; and Ref. 19: p. 22]. In spite of this traditional emphasis on military needs, there is an increasing awareness among Soviet leaders of the importance of a strong civilian economy, and of the military interdependence with civilian basic research.

> Primary preoccupation with questions of national security, which underlay the science policy efforts of both (the United States and the Soviet Union) in the 1950s and 1960s, has given way, more or less, to greater concern with applying science and technology to solve domestic civil sector problems. [Ref. 17: p. 300]

The deeply rooted Russian interest in military over civilian technology, dating from the tsarist reign of Peter the Great will, however, ensure the continued predominance of the military in Soviet science and technology for the foreseeable future [Ref. 17: p. 12].

F. SUMMARY

This chapter has briefly reviewed the structure of Soviet science. Structure significantly affects the Soviet ability both to pursue basic research and to incorporate technical innovations into production cycles. The structural barriers to technical application are examined in Paul Cocks' analysis of Soviet science, Science Policy: USA/USSR, Volume II: Science Policy in the Soviet Union [Ref. 17]. The cultural characteristics influencing this structure and their subsequent impact on Soviet basic research will be addressed in the following chapter.

V. RUSSIAN CULTURE AND SOVIET SCIENCE

A. THE PREDOMINANCE OF RUSSIAN CULTURE IN THE SOVIET UNION

Georgraphically, the Soviet Union spans the Eurasian landmass, touching nations of Europe, Central Asia, and Asia. This expanse is reflected in the range of nationalities governed by the fifteen republics of the Soviet Union. Within more than one hundred nationalities are twenty-three major ethnic groups, including the fifteen nationalities for whom the republics are named, the Tatars, Germans, Jews, Chuvash, Peoples of Dagistan, Bashkirs, Mordvins, and Poles [Ref. 22: p. 264]. These groups vary widely in religious and cultural backgrounds. Religious traditions include Russian Orthodox, Moslem, Catholic, Christian, and Jewish faiths, while diverse cultures--European, Caucasian, Central Asian, and Asian--range along the Soviet borders. Predominant among these many groups, however, are the Russian people.

Russian dominance is felt in most facets of the Soviet system including science. This dominance is maintained through a variety of mechanisms. The Russians are still the largest national group by population (over fifty-two percent in 1979), although this lead is slipping as other groups, particularly Muslim Asians and Caucasians, sustain higher

birthrates [Ref. 22: p. 265]. In addition to this numerical superiority, Russians enjoy a disproportionate influence in the Party and government. In 1981, Russians accounted for sixty percent of the Party membership and sixty-five percent of the full and candidate Politburo members and Central Committee Secretaries [Ref. 22: p. 270]. The universal use of Russian as a primary or secondary language is another mechanism for exerting Russian influence.

> ... The pressure to learn Russian, and even to use it in preference to one's native language, is considerable. Many governmental, economic, and Party activities are conducted almost exclusively in Russian, even in the non-Russian republics. The same is true of the Soviet armed forces, much of higher education, and other aspects of life. The message, although nowhere spelled out in so many words, is clear: If you want to get anywhere in life, learn Russian. [Ref. 22: pp. 268-9]

An additional mechanism is the migration of Russians to non-Russian republics [Ref. 22: pp. 265-6].

> Unfavorable economic and social conditions, particularly in the rural areas of their own ethnic territory, provided the impetus for the out-migration of millions of Russians to other parts of the country, including the non-Russian lands, where their numbers rose from 6.2 million in 1926 to 23.9 million in 1979. The vast majority of these Russian migrants settled in urban areas and in many instances took the better jobs, thereby foreclosing opportunities for upward mobility by the local inhabitants. Once a Russian presence is established it takes on an inertial character, since a large Russian population in a non-Russian area provides the linguistic and cultural atmosphere attractive to other Russian migrants. [Ref. 20: pp. 288-9]

Soviet science serves to illustrate other mechanisms supporting Russian dominance. Three aspects of organizational structure enhance Russian influence. First, the

academies and ministries of the fifteen republics are subordinate to both their republic Council of Ministers and their Russian dominated USSR counterparts. Thus, "... given the highly centralized Soviet system and its distinct set of R&D priorities ... republic and local involvement in science planning and management remains substantially circumscribed" [Ref. 17: p. 299]. Second, the republic organizations replicate the national structures based on Russian culture, thus transmitting the Russian heritage to the non-Russian republics. "A 'historical tradition' must be transmitted, and one of the ways that is done is through patterns of organization, education, communication, and reward..." [Ref. 23. p. 57]. The third aspect is the common practice in the republics of placing a Russian as the organization's second-in-command [Ref. 22: p. 270-2; and Ref. 24: p. 130]. In addition to these aspects, the greater specialization of republic ministries and academies serves to limit their national influence.

Another mechanism is the disporportionate number of Russians in the scientific community. As with the Party and government, the concentration of Russians in science is higher than their percentage by overall population. The percentages of scientific workers by national or ethnic origin in 1960 and 1961 are given in Table VII [Ref. 25: p. 126]. In addition to this concentration by population, the

TABLE VII

Scientific Workers by National or Ethnic Origin, USSR, 1960 and 1961

	1960		1961	
	Thousands	Per cent	Thousands	Per cent
Russian	229.55	64.8	263.84	65.3
Ukrainian	35.43	10.0	40.95	10.1
Jewish	33.53	9.5	36.17	8.9
Georgian	8.31	2.3	9.29	2.3
Armenian	8.00	2.3	9.12	2.3
Byelorussian	6.36	1.8	7.24	1.8
Azerbaidzhan	4.97	1.4	5.42	1.3
Uzbek	3.75	1.1	4.51	1.1
Tatar	3.69	1.0	4.31	1.1
Lithuanian	2.96	.8	3.32	.8
Latvian	2.66	.8	2.95	.7
Kazakh	2.29	.6	2.66	.7
Estonian	2.05	.6	2.30	.6
All other ethnic groups of the USSR	7.98	2.3	12.05	3.0
Foreign Nationals	2.63	.7	2.82	.7
Total	354.16	100.0	404.13	100.0

Source: Soviet Research and Development

research institutes are geographically concentrated. A majority of science establishments are located in the Western portion of the USSR in the Russian and culturally similar Ukrainian republics.

> Moscow alone boasts one-fourth of all scientific workers, 34 percent of all doctors of science and 26 percent of all candidates of science. Here also are the most qualified researchers: 45 percent of all scientists with the title of professor; 72 percent of all full members and 64 percent of all corresponding members of the USSR Academy. In just three cities--Moscow, Leningrad, and Kiev--are concentrated one fourth of all scientific institutions, nearly 40 percent of all R&D being performed in the country, and more than 45 percent of the total allocations to scientific research and development. [Ref. 17: p. 50]

Finally, the quality of the republic science establishments is considered inferior to those in the Western USSR.

> The large number of poorly qualified scientists attracted by the profession's prestige and material rewards, combined with party interference in scientific appointments, constitutes a major weakness of Soviet science. With the partial exception of the Ukrainian Academy of Sciences, the Academies of the individual Soviet republics are mostly staffed by such people, and their productivity is practically nil. [Ref. 20: p. 229]

As a result of these and other mechanisms, Russian culture has been the primary influence shaping the characteristics of Soviet science. "In spite of apparently genuine efforts by Lenin to curb Great Russian chauvinism within Soviet territory, the dominance of the Russian nationality was and continues to be one of the basic facts of life in the Soviet Union today" [Ref. 22: p. 263]. Therefore the structure of Soviet science will be considered in light of its Russian origin.

B. CHARACTERISTICS OF RUSSIAN CULTURE

Russian culture evolved as a unique mixture of Byzantine, Asian, and European characteristics. The Byzantine Empire exerted a strong influence on the state of Kievan Rus from the ninth through the fifteenth century, when Constantinople fell to the Turks. This influence included a tradition of centralism and autocracy; "... the Cyrillic alphabet ...; Orthodox Christianity; and the concept of the God-Emperor, who combined in his person the authority of the Pope and the Emperor" [Ref. 22: p. `]. Early Russia was also strongly affected by two cent ies of rule by the Mongol-Tartar khans from the thirteent' entury until 1480. The Mongol rule "... reinforced the By...ntine inclination toward centralism and autocracy..." [Ref. 22: pp. 14-5] and accustomed the Russian people to cruel, despotic rulers and barbarism. For several centuries, then, Russian culture was largely insulated from European influences.

> Long isolated from Western Europe, Russia grew up without participating in developments that many Russians, taking pride in their unique culture, find of dubious value. Russia was never a part of the Roman Empire. She never recognized the temporal or spiritual authority of the Roman pope. The Renaissance and the Reformation both passed her by; the scientific revolution was in Russia only a feeble reverberation of the explosion in the West. Her political and social revolution came so late that it seemed strange and frightening to more "sophisticated" nations who had experienced similar upheavals in earlier centuries. Russia is, as a result, the most unusual member of the European family--if indeed she is European at all; the question is still open to debate, particularly among the Russians themselves. [Ref. 26: p. 12]

European influence was to wait until the reign of Peter the Great in the eighteenth century. "By the end of his life, Peter had forcibly Europeanized Russian, dragging her reluctantly into the 'modern' world" [Ref. 26: pp. 12-3]. This modernization process included an infusion of Western scientific thought and technology--a sporadic but recurring theme in subsequent Russian history.

> No spontaneous movement to develop science grew in Russia. Instead scientific centers had to be developed by the central government based on Western models. [Ref. 19: p. 28]

Peter the Great's efforts to incorporate Western science culminated in 1724 in the founding of the Russian Academy--the first scientific organization in Russia, later renamed the USSR Academy of Sciences--establishing a Russian tradition of state-directed science.

The significance of the Russian isolation from European thought and their belated importation of Western science is highlighted by Kuhn's observation that

> ... only the civilizations that descend from Hellenic Greece have possessed more than the most rudimentary science. The bulk of scientific knowledge is a product of Europe in the last four centuries. No other place and time has supported the very special communities from which scientific productivity comes. [Ref. 10: p. 168]

This suggests that the non-European attributes dominant in Russian culture prior to the eighteenth century caused the initial reliance on Western science and technology. This Russian character, already largely formed by the time of

Peter the Great, strongly influenced the subsequent development of science in Russia and the Soviet Union, as well.

In terms of the cultural characteristics discussed in Chapter III, Russian culture is high context and has a low tolerance for uncertainty. Harsh historical and environmental conditions generated a national angst toward instability and chaos, and caused the evolution of social structures emphasizing group survival to minimize uncertainty. Chaos is a function of factors both external to the group and internal to the individual members. Both the external and internal factors encouraging chaos must be controlled by group authority.

> Whether under czars or commissars, Russians have traditionally had a deeply ingrained fear of anarchy and the centrifugal forces that tug at the unity and stability of their vast state.... Centralized despotism with the czar or Party Leader projected as the personification of the state has been Russia's historic answer to the chaos it feared.... Russians prize order and security as much as Americans prize freedom. Most Russians ... are so genuinely dismayed at the unemployment, crime, political assasinations, drugs, and labor strife in American life that they prefer instead the disadvantages of censorship, police controls, arbitrary arrests, labor camps and enforced intellectual conformity... It is not only the chaos around them but the anarchy within themselves that Russians seem to fear.... Theirs is an imposed discipline, not an ethnic instinct for regimentation. [Ref. 7: pp. 333-5]

Control of chaos is achieved by establishing supremacy of the group over the individual and relying on incrementalism to prevent instability. The resulting Russian characteristics are consistent with the attributes of a high

context culture and uncertainty avoidance societal norms and connotations (Tables III and IV). The importance of the group in Russian culture is illustrated in a statement by the Soviet biologist, V. W. Inyushin:

> "A personality ... cannot have any independent, intrinsic value, because every individual is, first and foremost, part of a whole, namely of society. Society's chief need is progress.... (The) effect of progress should be to produce a harmonized society, one in which each person's aspirations combine with others' for the good of the community, like the various cells of a body.... We must harmonize society on a scientific basis, and for that purpose people must forego their private tastes and ambitions for the sake of general progress." [Ref. 24: p. 191]

The intense group-orientation of Russian culture provides the basis for a high context system. "In cultures in which people are deeply involved with each other ... --what (are termed) high context cultures--simple messages with deep meaning flow freely" [Ref. 15: p. 39]. This style of interaction requires the inculcation of a strong shared image as a basis for consensus and a standard for conformity. In addition, this shared image serves as a framework enabling utilization and reliance on pattern recognition as an integral element of group interaction. As a high context, low tolerance culture, Russian characteristics include suppression of internal conflict and individualism; a need for consensus and conformity; intolerance toward new ideas, risk, and change; xenophobia; gerontocratic rule to restrain youthful inexperience and

impulsiveness; organizational inertia; central, hierarchical control structures; secrecy; committee rule projecting a unanimous front; incrementalism; and conservatism. As cultural extensions, Soviet science and science education reflect and reinforce these Russian characteristics.

C. STRUCTURE AND CULTURE

Soviet science is structured to enable Party and governmental control. Control is critical to the Soviet system to prevent instability and this consideration outweighs any potential benefit to be gained from greater scientific freedom. [Ref. 24: p. 49; and Ref. 18: p. 63]

> The Soviet government, like its Tsarist predecessor, has been ambivalent toward science. On the one hand, it sees science as indispensable for economic modernization and for enhancing Soviet military power; on the other hand, the regime distrusts the scientific spirit with its critical attitude towards authority and individualistic approach to problem-solving. The evolution of science as an autonomous social activity carries the dangers of professional exclusiveness, elitism, and the assertion of rationalistic modes of thought. Manifestations of dissent in recent years among scientists testify to the reality of these dangers and make ideological problems a continuing basic concern of Soviet science policy. [Ref. 17: p. 3]

The requisite control of science is achieved through positive and negative organizational mechanisms, and through indoctrination and constraint of the individual.

Positive organizational mechanisms actively transmit control downward from the top Party and governmental organs. This control is maintained through the hierarchical

structure subordinating the ministries, educational system, and academies to the USSR Council of Ministers and the Politburo. The power projected through the national annual budget and five-year and long range plans enables the Council and Politburo to determine science policy and actively participate in translating policy into directives and resource allocations. This control is reinforced by the overview and enforcement of plan directives by the Party organization paralleling the hierarchy of science structures. Centralized control is also enhanced by the increasing concentration of scientific research in large institutes employing thousands of scientific workers and in research complexes where several institutes are colocated [Ref. 17: pp. 183-4 and 274]. This trend toward concentration of research and development efforts reduces administrative fragmentation and facilitates centralized control. Concentration has the additional advantage of reducing duplicate research efforts.

Negative organizational control mechanisms serve to dampen tendencies toward conflict and radical change. By discouraging these tendencies, negative mechanisms stabilize and moderate the system. One mechanism fostering incrementalism is rule by committee throughout the hierarchy of science organizations. Authority in Soviet organizations typically is concentrated in subcommittees within larger

committee structures. These subcommittees are headed by a chairman or secretary who functions as the primus inter pares. Decision making is a group process--emphasizing consensus, confining pre-consensus debate internally, and culminating in unanimous pronouncements. The consensus building process must balance conflicting viewpoints and needs of the committee members. This encourages incremental policy making. Committee rule is employed at all levels--the Politburo, Council of Ministers, state committees, ministries, and academies. At the level of the research institute, power is concentrated in the hands of the director; however, the Academic, or Learned, Council participates in the decision making process.

> ... (The) dominant impression from Soviet publications and from interviews is that the division of power between the director and the learned council produces collegial decision making by unanimity, and therefore a tendency toward conservatism and inertia in the selection of projects. [Ref. 23: p. 39]

A second dampening mechanism is gerontocratic rule. In science, gerontocracy is maintained both in the higher average age of the established scientist and, more importantly, in the greater authority commanded by older scientists.

> ... (The) Soviet scientific elite is considerably older than its American counterpart. In 1970, 58.5 percent of Soviet academicians where over sixty, compared to 50.6 percent of American members of the National Academy of Sciences. But that statistic understates the difference, for Soviet academicians have vastly more power over research resources than do the American members of

> the NAS. A more relevant comparison, in terms of influence over resources and research directions, might be the average age of (American National Science Foundation) advisors (forty-seven years in 1970). [Ref. 23: p. 45-6]

The Soviet practice of employing scientists as administrators in academy, higher educational, and military research institutes reinforces the preponderance of age. The power of resource allocation, bolstered by the policy of block funding to institutes, lies with the administrator. For the Soviet scientist to pursue research projects of personal interest, he must assume administrative duties.

> Under a block-funding system, formal rank gives power over resources and research directions, while under project-grant system it gives very little. Therefore, the best American scientists have no incentive to hold administrative positions, but for the best Soviet researchers it is an important part of scientific success. [Ref. 23: p. 36]

Advancement in the Soviet system, however, is a gradual process requiring the completion of advanced degrees and the cultivation of influential contacts. Thus, "... a Soviet researcher is relatively old by the time he reaches a position of sufficient power to control resources and impose his ideas" [Ref. 23: p. 36]. One result of this system is that senior scientists reserve the prerogative to conduct basic research and assign the applied research projects to junior scientists [Ref. 23: p. 47]. Another result is the institutionalization of conservatism and the curbing of youthful impulsiveness.

The planning and budgetary process is another mechanism moderating change. The build on approach--"improving and scaling up existing processes rather than ... developing basically new processes" [Ref. 17: p. 127]--is characteristic of Soviet planning and is encouraged by the budgetary process.

> ... (The) State Budget in the Soviet Union is an annual budget. There is no five-year budget that can be linked to the five-year macroeconomic plan. Funds--as the basis for obtaining material and technical resources--are distributed only for one-year periods. Such a short time horizon prevents the development of a genuine investment toward R&D outlays that is oriented to long-term returns. On the contrary, it reinforces the dominant tendency to plan "from the achieved level" and to focus on inputs rather than results. [Ref. 17: p. 102].

Thus the budget and national plans support incremental changes to the status quo.

The rigidity of Soviet organizational hierarchy further constrains the potential for unanticipated change. This rigidity discourages interaction between research institutes. "(The) structure of decision making is predominantly vertical and thus substantially inhibits lateral communication, cooperation, and coordination" [Ref. 17: p. 17]. Communication of new ideas is additionally circumscribed by secrecy, censorship, and limited access to foreign scientists and publications.

In addition to positive and negative organizational mechanisms, social control is accomplished through

indoctrination and constraint of the individual. Social indoctrination occurs throughout the life of the individual, inculcating those traits conducive to maintaining the controlling social order. In the Soviet Union, social indoctrination reinforces Russian characteristics stressing conformity, subordination, and collectivity [Ref. 22: pp. 46-74]. In science, the emphasis on conformity serves to repress exceptional research abilities and independent ideas. Such abilities and ideas threaten to disrupt the predictability of the system and may attract critical attention. "(A) researcher learns from his earliest years to conceal his views, feelings, and abilities. Any kind of brilliance is especially dangerous, as it may arouse suspicion or hostility on the part of his superiors" [Ref. 24: p. 51]. Because of the considerable power which the superior exercises over an individual's career and research opportunities, subordination outweighs individual preferences. Hedrick Smith noted this tendency in a discussion with a Soviet scientist.

> "A man with his own ideas is in difficulty because the essence of the game is to understand the desires of superiors, or better yet, to anticipate their desires. It is bad to get the reputation of being difficult to work with or being too knowledgeable." [Ref. 7: p. 391]

This acceptance of authority buttresses gerontocracy in research institutes. "(Leading) Soviet scientists ... find it entirely appropriate that a laboratory or even an entire

institute embody the ideas of a single leader, and that younger researchers in the laboratory remain that leader's pupils for a substantial part of their professional lives" [Ref. 23: p. 47].

The precedence of the group is another value instilled by indoctrination. Receiving collective approval and contributing to the group are paramount goals for the individual. Sociological surveys of technical specialists and researchers working in Voronezh in 1974 indicate that collective approval is valued more highly than the opportunity to pursue creative work [Ref. 23: pp. 160-1]. In addition, conflict within the group is considered to be disruptive to both the collective good and scientific research.

> The late Academician A. V. Nikolaev once stated a belief that most Soviet researchers would probably share: "Fights and arguments are counterproductive in a scientific community," especially public controversy. [Ref. 23: p. 59]

The suppression of conflict and the subordination of creativity to the collective good are additional factors preventing radical change.

In addition to deeply ingrained social values which discourage individualism, the individual's environment is controlled by limiting exposure to new ideas. Potentially disruptive foreign influences are of special concern to the Soviet system. These influences are limited both by

controlling travel by Soviet scientists abroad and travel by foreigners in the Soviet Union, and by restricting access to foreign publications.

> Rigidity ... restricts Soviet scientists' contacts with the outside world. It is still a major accomplishment for a Russian scientist to get to an international meeting, let alone make a prolonged visit to a laboratory in another country. [Ref. 8: p. 328]

It is not only exposure to foreign ideas that is controlled, however. Secrecy is one means of limiting the dissemination of new ideas. In addition, a lack of mobility of scientists between research institutes prevents parochial and stable viewpoints from becoming unsettled by fresh ideas. The transfer of personnel is limited both by the system and by individual preference [Ref. 17: p. 267]. Transfer can be denied the individual; but, in addition, the importance of gaining administrative positions provides a strong incentive to remain in an organization. "Soviet researchers have every interest in staying in one place, cultivating their relations with colleagues and superiors, and gradually rising to positions of influence" [Ref. 23: p. 36]. As a result, transfers between institutes are infrequent, as are transfers between fields and specialties [Ref. 7: p. 254; and Ref. 17: p. 267]. These limitations in mobility and access to foreign ideas contribute to the circumscription of communication resulting from the rigid hierarchy of organizations.

Structural and social mechanisms, then, enable the central control and preserve the system stability which are fundamentally important in Russian culture.

> (The) differences in (Russian and American science) organization and management ... stem from profoundly different national attitudes toward authority, uncertainty, and conflict.... The United States has a political and national culture with a high tolerance for risk and uncertainty, individual initiative, open conflict, administrative informality and fluidity, disrespect for established beliefs and persons, and high mobility. The system as a whole appears to show a zest for the unplanned opportunity. The Soviet system appears to choose, wherever it can, the greater predictability. [Ref. 23: pp. 57-8]

D. SCIENCE EDUCATION AND CULTURE

Science education lays the foundation for the predictable and stable system of Soviet research. Education serves as both an indoctrination and control mechanism. As an indoctrination mechanism, education is an integral component of the socialization process instilling the collectivist values of Russian culture. Collective responsibility is taught throughout the course of Soviet education. In his observations of the education system and discussions with former Soviet journalist, Leonid Vladimirov, Hedrick Smith notes that

> ... youngsters are instilled with a conformist, collectivist zeal. "The greatest offense a child can commit in kindergarten is to be different." observed Vladimirov. [Ref. 7: p. 212]

This indoctrination continues through the individual's life both through further education and group pressure.

Education at the secondary school and higher educational institute levels emphasizes a traditional style of science training. Classes are highly structured and students are rigorously taught the body of accepted scientific theory.

> Students have practically no freedom of choice in their programs, and must attend many strictly required lectures. Little attention is paid to developing creative skills.... (At) Soviet universities great emphasis is placed on mechanically stuffing the memory. [Ref. 20: pp. 229-30]

The implication of rote-learning fixed material--the method utilized at both the secondary and higher educational levels [Ref. 7: p. 221; and Ref. 22: p. 43]--is twofold. Smith notes that

> ... the cost of the stifling conservatism of the Soviet method is in the lost spontaneity of students and in the Soviet system's failure to teach them to think creatively for themselves or to ask imaginative, probing questions. [Ref. 7: p. 223]

On the other hand,

> ... the positive side of the no-nonsense Soviet approach to classroom education is that great gobs of materials are committed to memory and children are drilled to mastery of fundamentals. In subjects like math and the natural sciences which lend themselves to that method in the early years, results are impressive. [Ref. 7: p. 222]

This style of science education inculcates the student with the shared image of the scientific community and reinforces the use of paradigms and pattern recognition in problem solving.

Science education as a control mechanism limits access to the scientific community. The uneven quality of

education throughout the Soviet Union is accounted for at the higher educational level with intensely competitive entrance examinations [Ref. 7: pp. 207-8; and Ref. 20: p. 235]. Thus, although "... Soviet leaders have sought to use the schools as mechanisms of social mobility for politically 'correct' social groups, mainly workers and peasants ..." [Ref. 20: p. 234], the system may actually be exacerbating class order.

> (In) spite of a nationally standardized core curriculum set in Moscow, variations in the quality of Soviet education are so great that both Soviet and Western scholars now suspect that the educational system is rigidifying and reinforcing the class structure of Soviet society. [Ref. 7: pp. 207-8]

For science, "... the data of Soviet survey research suggests that the children of the intelligentsia and other white collar workers have a much better chance of getting into engineering and other technical specialties than the children of workers and peasants" [Ref. 23: p. 144]. This additionally tends to reinforce Russian predominance in science.

The selection process also enables control by the Party over the access of science to persons with politically desirable traits [Ref. 24: pp. 44-6]. Access to basic research is of particular concern due to the greater contact of the researcher with new ideas and the disruptive potential of independent thinking. Exposure to the unpredictable and volatile atmosphere of basic research is limited to a small elite.

> The Soviet system ... limits access to basic science to a chosen few, who are picked at an early age. A crucial selection point is admission to a top-ranking under-graduate program. Only a handful of the very best universities offer a broad theoretical education in the sciences; the rest provide narrowly focused applied programs that do not prepare the students for basic research. But competition for the best schools is stiff. Consequently, despite the fact that many more Soviet students study science than American students do, few study basic science. [Ref. 23: p. 43]

Thus, "... uncertainty is reduced by careful control over access to the basic-research system" [Ref. 23: p. 58].

Science education in the Soviet Union, then, generates a strong shared image emphasizing paradigms and pattern recognition. This adherence to accepted scientific theory is reinforced with the indoctrination of collectivist values. In addition, exposure to the new ideas and independent style of thinking associated with basic research is limited to a reliable, controllable elite. Science education, therefore, contributes to the control and stability of Soviet science.

E. SUMMARY

Russian culture significantly affects the structure and characteristics of Soviet science. The deeply ingrained Russian fear of chaos and instability translates into structural mechanisms which permit central control of science and encourage incrementalism. The scientific community is strongly indoctrinated in accepted theory and in collectivist values which perpetuate existing patterns of

thought. Russian culture, then, acts to stabilize the process of science. The implications of this stability on the Soviet ability to conduct scientific research will be discussed in the concluding chapter.

VI. IDEOLOGY AND SOVIET SCIENCE

A. THE INTEGRATION OF IDEOLOGY AND SCIENCE

Science is integral to Soviet ideology in two respects. First, the Soviet regime asserts the scientific validity of Marxism-Leninism to legitimize the ideological basis of Party rule. The view of science as objective and authoritative lends prestige to Soviet ideology as "... dialectic materialism is a scientific outlook derived from science itself" [Ref. 27: p. 153]. This linkage was established at the outset when compatibiilty with contemporary scientific theories was argued by Marx, Engels, and Lenin to gain popular support for their theories. However,

> (neither) Engels nor Lenin had any significant amount of training in any of the sciences, and even if they had had such training, their scientific views would now be hopelessly dated by the rapid progress of science in the last five decades. [Ref. 27: p. 190]

The rigid nature of Soviet ideology, however, has ossified Marx's, Engels', and Lenin's applications of popularized science into Party doctrine.

> That the out-dated views of certain Marxists of the last century should continue to be regarded as fundamental scientific truths is symptomatic of the unfortunate and unthinking dogmatism which characterises (sic) much of dialectic materialist philosophy. [Ref. 27: p. 190]

This enshrinement of Marx's, Engels', and Lenin's dabblings in contemporary scientific theories and their philosophical

implications results in potential conflict between Soviet doctrine and modern scientific theories. Thus, unless carefully controlled, science may threaten rather than validate the regime. This danger is exacerbated by the disruptive potential of independent thinking associated with basic research.

The initial role of science in Soviet ideology, then, was as a legitimizing agent. Science, however, plays a second role--as a vehicle for achieving socialism.

> Kremlin leaders see their ideology as being synonymous with science, and they have long regarded the latter as an indispensable tool for modernizing Russia. The early Bolsheviks believed that science would "conquer Russia both as a state of mind and as a state of nature...." Leonid Brezhnev reaffirmed this basic commitment on the 250th Anniversary of the USSR Academy of Sciences. "Socialism and science are indivisible," he emphasized. "Only by relying on the latest achievements of science and technology is it possible to build socialism and communism successfully." [Ref. 17: p. 2]

Science and technology are vital factors in determining future military and industrial capabilities--capabilities required to protect the socialist state from external threats and achieve a means and level of production congruent with socialist and communist objectives. The conviction of the Soviet leadership that science is elemental to socialist progress is reflected in the concentration of technological backgrounds among the Party and governmental elites, the formal representation of the science community at the highest policy-making level, and the significant allocation of resources to scientific and

technological efforts. An additional indication of the leadership's growing awareness of the linkage between scientific achievements and socialist goals is the inclusion of science in the annual State plan--beginning in 1949 when the introduction of new technology was generally addressed and expanded in 1956 to include assignments for scientific research [Ref. 17: p. 7]. The emphasis on science has increased over the last three decades.

> An implied feature of Soviet thought in the 1970s was the movement towards a broader concept of science policy and the closer integration of R&D with the totality of domestic and foreign policy.... (Gvishiani), the deputy chairman of the GKNT affirmed, "(R&D management and planning) is about the future, about the long-term development of socialist countries, about the very fate of the world and socialism. For now only that system can win which is able to assure itself a vanguard position in scientific and technical progress." [Ref. 17: pp. 255-6]

The relationship of science to ideology--both as a legitimizing agent and a vehicle for socialist goals--evokes the highest level of Party and government interest. The resulting interaction can influence science in two ways--ideology may dictate the actual content of scientific theories and ideology may determine science priorities for resource allocations.

B. IDEOLOGY AND CONTENT

The organizational structure of Soviet science enables the Party and government to exert considerable control over scientific research--control potentially sufficient for the

regime to dictate the content of scientific theories. Despite this potential, ideological incursions into theory content have been relatively infrequent. Several factors contribute to this lack of interference. First is that, with the exception of Stalin, Party leaders have not presumed to dictate theoretical precepts.

> (In) the years immediately after the Revolution almost no one thought seriously that the Communist Party's supervision of intellectuals would extend from the realm of political activity to that of scientific theory itself. Party leaders neither planned nor predicted that the Party would approve or support certain viewpoints internal to science; indeed, such endorsement was fundamentally opposed by all the important leaders of the Party.... (A) condition free of such entailment actually obtained in the late fifties and sixties for all the sciences except genetics, and for genetics as well since 1965. [Ref. 28: p. 10]

This prediliction is encouraged by three additional factors. Again, the threat of conflict between modern scientific theories and the out-dated theories associated with Engels and Lenin is blunted by the ambiguity of interpreting both Marxist-Leninist and philosophical implications of modern scientific theories. Scientists have been able to turn this ambiguity to their advantage and, even during periods of ideological interference, have successfully defended new theories.

> The scientists of the immediate postwar period began reading Marx and Engels on philosophical materialism in order better to answer their ideological critics. They developed arguments more incisive than those of their Stalinist opponents; they constructed defenses that exposed the fallacies of their official critics yet were in accord with philosophical materialism and--most important of all--preserved the cores of their sciences. [Ref. 28: pp. 20-1].

Ambiguity enables scientists to maintain the distinction between science and the philosophy of science. Philosophy of science then absorbs the brunt of ideological criticism and buffers science content from Party influence.

A second factor encouraging non-interference in theory content is the availability of alternate control mechanisms to avert political conflict. "Bourgeois scientists" were initially subjugated in the years following the Revolution through political examinations and purges. Imprisonments, executions, and dismissals from academic positions were intended to break the spirit and assure the political reliability of the scientific community. In addition, positions in academies and research institutions were increasingly filled with Party supporters.

> Functionally, the purges had begun in Soviet academic institutions as a means of personnel replacement. In the late 1920's, this renovative technique was used to oust bourgeois academicians of certain institutions in order to replace them with supporters of the Communist Party. These replacements were frequently persons of inferior scholarship whose enthusiasm for social reconstruction commended them to preferment.... Even at this time, however, no attempt was made to impose ideological interpretations upon the work of scientists. ... [Ref. 28: p. 13]

Since the revolution, the structural mechanisms discussed in Chapter V were gradually incorporated to maintain control of the scientific community. These mechanisms ensure the political reliability of the scientist through indoctrination, controlled access to research and foreign influences,

and Party overview. Other mechanisms retard the dissemination and acceptance of new ideas, thereby defusing potentially disruptive influences. The Party is thus able to control science and scientists without imposing theory content.

The third factor encouraging non-intervention is the pragmatism of the Soviet elite. While control remains the overwhelming priority, the second priority is to maximize scientific and technological advancement necessary to pursue socialist goals. Scientific advancement, however, requires a degree of independent thinking and autonomy for the scientific community. The regime must, therefore, balance the need for control with the need for scientific progress. Non-interference in science content is an element of this balance.

The above factors--prediliction, ambiguity, availability of alternate controls, and pragmatism--militate against the Party dictating theory content. Generally, these factors have been sufficient to preserve scientific integrity. The potential for interference remains, however, and exceptions have occurred, particularly during the Stalin period.

> No longer could it be hoped that Party organs would distinguish between science and philosophical interpretations of science. Evidently Stalin had no intention of making such distinctions, and he was in control of the Party. It soon became clear that other scientific fields (than genetics), such as physics and physiology, were also objects of ideological attack. [Ref. 28: p. 19-20]

The epitome of ideological interference occurred in genetics with the influential rise of T. D. Lysenko. Lysenko espoused a genetic theory which blurred the distinction between genotype (the genetic composition of an organism) and phenotype (the observable characteristics of an organism resulting from the interaction of the genotype and the environment) and argued that environmentally acquired characteristics could be inherited.

> Lysenko ... described heredity in terms of the relationship of an organism to its environment rather than in the traditional sense of the transmission of characters from ancester to descendant.... The heredity of a living body, according to Lysenko, was built up from the conditions of the external environment over many generations, and each alteration of these conditions led to a change in heredity. This process he called the "assimilation of external conditions." Once assimilated, these conditions became internalized--that is, a part of the nature, or heredity, of the organism. [Ref. 28: pp. 222-3]

Lysenko gained support for this theory from the political regime by arguing its compatability with Marxism-Leninism and its greater utility to the needs of the socialist state. Loren Graham describes four basic elements in Lysenko's arguments. First, Lysenko misrepresented classical genetics as claiming that genes are immutable--thus conflicting with the precept of dialectical materialism that change is an elemental and universal process. However, contemporary geneticists proposed that genes do mutate and that "biological evolution is built on the concept of great changes resulting from minute variations occurring over vast

periods of time" [Ref. 28: p. 232]. Lysenko's second argument also misrepresented classical genetics. According to Lysenko, classical genetics indicated that genes were immune from external effects. This conflicted with Stalin's interpretation of dialectical materialism that "'not a single phenomenon in nature can be understood if it is considered in isolation, disconnected from the surrounding phenomena'" [Ref. 28: p. 234]. Classical geneticists, however, had shown that genetic mutation could be induced by external stimuli--radiation--in experiments conducted by H. J. Muller in 1927. Lysenko's third argument was the greater responsiveness of his theory to the immediate needs of the Soviet state. The theories of classical geneticists were unable to offer immediate control of the rate or type of genetic mutations while Lysenko and his followers claimed that "'it is possible, with man's intervention, to force any form of animal or plant to change more quickly and in a direction desirable to man'" [Ref. 28: p. 235]. This issue of control was central to Lysenko's fourth argument as well. Classical geneticists utilized statistical probability to describe the occurrence of mutations over time. Lysenko argued that the use of probability implied random action. This conflicted with the dialectical materialist supposition in the laws of nature and determinism [Ref. 28: pp. 230-6].

These arguments appealed to both Stalin and Khrushchev. Lysenko's theories were officially endorsed in 1948 after inbred hybridization of corn crops dramatically failed to increase crop production during the agricultural collectivization drive. Inbred hybridization required the yearly distribution of freshly hybridized seedcorn and the intensive use of industrially produced mineral fertilizers. The Soviet agricultural system was unable to support these needs and, while American crops flourished, Soviet crops failed. Rather than question the Soviet system, however, the regime questioned the validity of inbred hybridization.

> (The) Bolshevik government was not prepared to blame itself or its ideology for this or for any of the agricultural fiascos that accompanied collectivization. The formula on theory and practice was not to be turned against Marxist-Leninist theory or its chief exponent... The government blamed the peasants, or rather, 'kulak agitation against corn', and showed an ever-mounting irritation with agricultural scientists who were using large sums for research and education but could not stop the steep decline in yields. The way was open for an attack on the biological theories of the scientists. [Ref. 27: p. 94]

In this atmosphere of controversy and frustration, Lysenko advocated theories involving labor-intensive methods "which (put) a scientific glow over primitive and retrograde farming" [Ref. 27: p. 94]. His theories gradually gained support from the Soviet leadership until officially endorsed by Stalin in 1948. Even as Lysenko's cornbreeding techniques failed to produce high yields, his skills at politicizing biological theories enabled him to retain official

favor, extend his theories to new applications, and dominate the field of biology.

> ... Lysenko skillfully shifted his emphasis from one nostrum to another--from the cluster-planting of trees, to the use of specified fertilizer mixes, to the square-cluster-planting of corn, to his methods of breeding cows for milk with a high butterfat content. At several moments in the 1950's criticism of Lysenko reached crescendos that seemed to indicate his inevitable demise, but each time he appears to have been rescued by highly placed individuals. Lysenko's resilience, his ability to take advantage of political situations and to curry favor, stood him in good stead. By this time, he was supported by an army of followers in the educational and agricultural establishments, men whose careers were intimately connected with Lysenko's school. [Ref. 28: p. 237]

Lysenko's political skill enabled him to dominate the biology community until 1965. With the downfall of Khrushchev in October 1964, however, Lysenko lost his primary source of support. Criticism increasingly surfaced until Lysenko was discredited and entered semiretirement in 1965 [Ref. 28: pp. 237-251].

The significance of the Lysenko affair lay in the measure of control exerted over the scientific community. Advocates of classical genetics were attacked by Lysenko and his followers and prevented from conducting research. Nikolai Vavilov, the leading Soviet classical geneticist, was removed as president of the Lenin Academy of Agricultural Sciences in 1935, and later died in prison following his arrest in 1940. Research in classical genetics was officially prohibited in 1948. In addition to banning

research, science textbooks and courses were revised and references to classical genetics eliminated [Ref. 23: pp. 215-8 and pp. 248-9]. Despite extensive influence, however, Lysenko's domination of biology was incomplete. Mark Adams traced the ability of one of the leading Soviet centers for biology research, the Kol'tsov Institute, to pursue research in classical genetics during Lysenko's predominance. Through careful political maneuverings, ideological adaptations, and maintaining a low public profile, Kol'tsov succeeded in protecting his institute from 1929 to 1939.

> (Despite) the arrest and exile of his key genetics researchers, Kol'tsov had managed within five years to reestablish genetics at the core of his institute, and to continue precisely the same research program that the earlier group had developed--this despite an almost total turnover in personnel. By the late 1930s, he was able to bring back several of the dispersed workers as well.... [Ref. 23: p. 186]

Even after Kol'tsov succumbed to ideological denunciations resulting in his dismissal as director in 1938, a small group of researchers within the institute, including N. P. Dubinin and B. L. Astaurov, pursued classical genetics research until 1948.

> In that year, of course, "ideological adaptation" was not enough, since the Lysenko meeting led to specific directives firing personnel, including Dubinin, and removing his group from the Kol'tsov Institute. Nonetheless, even under these harsh conditions, Astaurov managed to keep his cytogenetics work going in the institute. [Ref. 23: p. 190]

After Lysenko's fall in 1965, these geneticists reemerged as leading figures in Soviet biology--Astaurov as president of

the All-Union Society of Geneticists and Selectionists and director of the Institute of Developmental Biology and Dubinin as head of the Institute of General Genetics [Ref. 23: pp. 190-3; and Ref. 28: p. 251]. While demonstrating that Lysenko did not fully control genetics research, Adam's analysis of the Kol'tsov Institute illustrates that Lysenko's control was extensive and that scientific freedom in genetics was the exception--acquired only with difficulty and at great personal risk.

Lysenko's domination of genetics was not typical of other fields of Soviet science. However, the Lysenko episode fully exercised the potential for control of science content. While ideological interference in other fields has been minimal, the case of genetics serves to remind Soviet scientists that the regime's capability for interference, though latent, is substantial.

C. IDEOLOGY AND RESEARCH PRIORITIES

More significant and pervasive than ideological interference in theory content, is the impact of ideology in determining research priorities through resource allocations. Central planning and the inclusion of research assignments in the State Budget empower political leaders to judge the merit of lines of research and to determine their level of financial and material support. The Soviet preference to avoid duplication in research efforts significantly

increases the impact of this judgement. While the Soviet political elite has a concentration of backgrounds in technology, they are not science experts. Thus ideology may enter as a factor in their determinations. In addition, Soviet leaders, like Khrushchev, may overestimate their expertise.

> Since the thirties large areas of Soviet technology and science have been bossed by the half-baked executive specialist, the man who knows enough of a subject to play the authority so long as political and technical authority are confused.... Not Lysenko but Khrushchev is the prime specimen. He (fancied) himself a specialist in agricultural policy ... and many people (took) his pretentions seriously. [Ref. 27: p. 98]

Ideology also influences which general research areas receive political and material emphasis. Two priorities command the attention of Soviet leaders and receive the bulk of resource allocations. The first priority is the military. Emphasis on military requirements is both ideologically and culturally reinforced. Soviet ideology stresses the inevitability of confrontation between socialist and capitalist states. This confrontation, while not exclusively military, continually threatens to erupt into war. Lenin cautioned the Soviet people of their vulnerability to the implacable hostility of capitalist nations.

> The experience of the history of revolutions and great conflicts teaches us that wars, a series of wars, are inevitable. The existence of a Soviet Republic alongside of capitalist countries--a Soviet Republic surrounded by capitalist countries--is so intolerable to the capitalists that they will seize any opportunity to resume the war. [Ref. 29: p. 631]

The constant threat of war necessitates maintaining a strong military capability and economic base. The ideological assumption of eventual conflict is consistent with the traditional military emphasis of Russian culture. This tradition evolved in reaction to a history of repeated invasions from both the East and West.

> One of the most compelling historical antecedents for the USSR is that of invasion. In the twelfth century it was the Mongols, and in the ensuing years came the Teutonic knights, the Tatars, the Turks, the French and the Germans. Even the USA is included in this litany, the Soviets recalling the intervention in northern Russia and Siberia as an early attempt to smother the Revolution. This visceral preoccupation with invasion and encirclement continues.... [Ref. 30: p. 20]

The cultural and ideological prioritization of military requirements includes the dedication of scientific research efforts to advancing military technology. This dedication also has historical precedents.

> A preoccupation with defense technology and the political-military orientation of the state-directed effort are deeply rooted in Russian history. From the time of Peter the Great Tsarist governments were interested in applying technology largely to military purposes. [Ref. 17: p. 12]

The preoccupation of Soviet science efforts with military requirements results not only in the dedication of resources to military related fields but also reinforces the structural tendencies toward incrementalism. Military technology utilizes a high level of standardization compatible with mass production and minimal training requirements. [Ref. 30: p. 281]

> The overall approach to military research in the Soviet Union is derived, according to military leaders, from the Soviet military doctrine designed by Lenin. This doctrine is based on the theory of scientific communism and focuses on creating weapons characterized by simplicity, low cost, easy operation and maintenance, and few changes. The goals expressed in this doctrine encourage Soviet military science to be traditional, incremental, and conservative. The United States, by contrast, at least since World War II, has sought revolutionary weapons systems which require an innovative science and technology base. [Ref. 19: p. 20]

Thus ideological and cultural priorities for military requirements, and doctrinal emphasis on evolutionary and controlled developments in weapons systems, significantly affect both the areas of scientific research which receive resource support and the style of research conducted.

The second priority dominating scientific research efforts is the technological improvement of industrial production. Soviet ideology stresses that scientific research should serve the state, and that industrial capability is the economic basis for state power. Following the Revolution, scientists conducting research to advance "pure science" were criticized as bourgeois, forced to defend their research in terms of its practical benefit to the state, and coerced into devoting their efforts to applied research. In addition, the Party attempted to reorient Soviet science by filling the Academy ranks with engineers and allocating resources to institutes emphasizing applied research. This orientation receives priority from the Soviet leadership.

(A) "historic" task facing the USSR today, as defined by General Secretary Brezhnev at the 1971 Party congress and reaffirmed by the 1976 congress, is "to combine organically the achievements of the (scientific and technological revolution) with the advantages of the socialist economic system, to unfold more broadly our own, intrinsically socialist forms of fusing science with production. [Ref. 17: p. 252]

Unlike priorities for military requirements, the industrial orientation is not reinforced by traditional inclinations. "The Imperial Academy of Sciences, from the time of its foundation in 1725, was primarily theoretical in orientation and relatively isolated from industry" [Ref. 17: p. 10]. Thus the ideological stress on applied science must overcome traditional biases of the scientific community. Despite this obstacle, the regime incorporates new incentive systems and structural revisions to increase the responsiveness of scientific establishments to production needs and to encourage production facilities to adopt technological innovations.

Ideology, then, affects the distribution of resources to scientific research by emphasizing military and industrial requirements. This is consistent with the role of science as a vehicle for achieving socialism. Science's other role, as a legitimizing agent--and its corollary threat as critic--of Party rule generates the potential for ideological interference in theory content. This capability was dramatically demonstrated during Lysenko's dominance of Soviet biology. In general, however, the Soviet regime has

refrained from such interference and the influence of ideology has been primarily in determining research priorities.

VII. CONCLUSION

Soviet work in basic science is described by some as "excellent, comparable to that in America or anywhere else" [Ref. 8: p. 327] and "internationally recognized to be of high quality ... (maintaining) high standards throughout (Academy) laboratories" [Ref. 19: p. 27]. On the other hand, the output of Soviet science is inconsistent with this reputation and the level of Soviet investment.

> Why doesn't the Soviet Union lead the world in pure science? It spends as much as the United States, and it has many distinguished researchers, yet by any measure--whether Nobel prizes, frequency of citation by fellow specialists, origin of major breakthroughs, or simply quantity of publications--U.S. scientists lead their Soviet colleagues in most disciplines, and in many there is simply no competition. [Ref. 23: p. 31]

The Soviet lack of Nobel laureates in science is particularly striking. Of the 376 Nobel prizes awarded in physics, chemistry, physiology, medicine, and economics from 1901 through 1982, only eleven were received by Soviet or Russian scientists (see Table VIII). This contrasts with 151 awards received by United States scientists and sixty-three awards received by British scientists [Ref. 8: p. 327; Ref. 19: p. 4; and Ref. 31: pp. 407-9]. Thus, despite major expenditures on scientific research and maintenance of high standards in research techniques, the Soviet Union

TABLE VIII

Russian and Soviet Nobel Laureates in Science

1904--Ivan Petrovich Pavlov: Studies of the physiology of medicine

1908--Elie Metchnikoff: Work on immunity

1956--Nikolai Nikolayevich Semenov: Research on chemical reaction kinetics

1958--Pavel A. Cherenkov, Igor E. Tamm, Ilya M. Frank: Work resulting in development of cosmic ray counter

1962--Lev Davidovich Landau: Investigations of the low-temperature behavior of matter

1964--Nikolai Gennadiyevich Basov, Alexsandr Mikhaylovich Prokhorov: Work in quantum electronics related to lasers

1975--Leonid Vitalayevich Kantorovich: Economic analysis of optimal resource utilization

1978--Petr Leonidovich Kapitsa: Work on low-temperature physics

Source: Science and Technology in the Soviet Union: A Profile

fails to produce comparable levels of scientific breakthroughs. This apparent inconsistency is due largely to Soviet proficiency in normal scientific research and their cultural inability to accommodate to extraordinary scientific progress.

Russian culture and Soviet ideology generate an environment conducive to normal scientific achievements but inimical to extraordinary scientific advancement. Several attributes of Russian culture, manifested in and reinforced by Soviet organizational structures, are fundamental characteristics of normal science. Strong cohesiveness within the scientific community--both in shared images and common standards of scientific practice--is encouraged by the cultural emphasis on consensus and group orientation. The Soviet education system then transmits the community image and standards to new generations of scientists through rigorous traditional methods of science education. These educational methods, utilizing paradigm-based solution techniques, capitalize on the existing Russian prediliction for pattern recognition, which is characteristic of high context cultures. In addition, the low cultural tolerance for uncertainty and resulting preference for conservative, incremental change are compatible with the puzzle solving tradition of normal science. This tradition is dependent on a strong consensus regarding existing theory, which enables

the scientific community to clearly define research problem areas. The definition of research problems is well suited for incorporation into the Soviet planning process. The research institute is able to submit proposals with confidence in meeting stated objectives, and policy makers are assured of continuity and controlled change. Thus, Russian culture is highly congruent with practicing normal science.

The Soviet proficiency in normal science and puzzle solving contributed to their dramatic initial success in the space program. Robert Kaiser traces the evolution of the Soviet space program, pointing out the significant reliance on a static technological base.

> In basic rocketry (the Soviets) have made little progress. The rocket which carried the Soviet cosmonauts into space to meet the Americans in July 1975 had not been significantly modified for 12 years. It is based on the design of the V-2 rocket built by the Nazis in World War II. The Russians have never mastered high-energy rocket fuels, and still use kerosene. [Ref. 8: p. 321]

Soviet successes in space have resulted from creative and thorough exploitation of existing theories. Sergei Pavlovich Korolyov resolved the Soviet's inability to develop metals able to withstand the heat generated by large rocket engines by clustering smaller engines at the base of the rocket. Thus, four small engines provided the necessary thrust to launch the first Sputnik rocket. The same clustering techniques, this time using five clusters of four

engines, provided the additional thrust needed to launch the first man into orbit. Later, larger crews of two or three men were sent into space by selecting men of small frame, thus reducing the weight requirements [Ref. 8: pp. 320-325]. These accomplishments demonstrated the Soviet's ability to solve problems creatively adapting proven technology rather than developing new technologies and theories.

This same puzzle solving creativity is evident in the engineering and design of Soviet weapon systems. Captain J. W. Kehoe, in comparing United States and Soviet design practices, noted the ability of Soviet military designers to achieve simplicity and a high level of component standardization through innovative adjustments to proven technology.

> The simplicity of Soviet weapon systems is the result of clever conceptual designs to meet producibility, reliability and maintainability requirements.... The standardization in Soviet weapon systems appears to reduce system development risk and improve producibility and reliability. However, it also restricts technical innovation and system performance. These deficiencies are offset, in part, by highly skilled designers who are often able to conceive clever design solutions using obsolescent components. [Ref. 32: p. 709]

Thus, military technology as well as space technology demonstrates the Soviet proclivity for innovation and creative exploitation of known concepts. This innovative and thorough exploitation, which is the mark of superior capability in normal scientific research, is also evident in Soviet basic research.

> In several fields Soviet scientists do leading work by maintaining a steady effort in traditional specialties or established methodologies. For example, Soviet scientists hold a dominant position in electrochemistry, which has been neglected as too "settled" in the United States. American science searches restlessly for the new method or the original topic that appears to promise a breakthrough; but Soviet science often excels by following through with extensive surveying and cataloguing, such as extragalactic mapping or protein sequencing. Soviet scientists are also respected for traditional, large-scale expeditionary work in biology, geology, and oceanography, for which they have much more elaborate logistical support than American university scientists are usually able to get. [Ref. 23: p. 33]

Soviet scientists, then, are persistent and creative within the context of accepted theories. This is the creativity of high context cultures and the puzzle solving proficiency of normal scientists.

The Russian characteristics which enable this success in normal science, however, inhibit the divergent elements necessary for extraordinary science. Periods of extraordinary scientific progress are typified by new ideas, conflict, and radical change. Given the Russian fear of uncertainty, these elements are intolerable in the Soviet Union. They are, therefore, suppressed through structural mechanisms and social indoctrination which ensure conformity and incrementalism. In addition, the Soviet system discourages those conditions most likely to result in the perception of anomaly or the construction of new patterns of thought--the exposure of young scientists to basic research and the fresh insight provided by scientists changing

specializations. Basic research in the Soviet Union is dominated by older scientists, whose control is reinforced by the funding process and other structural mechanisms. This restricts access to basic research for younger scientists. In addition, Soviet science is characterized by a lack of mobility both between research institutes and between specializations. Thus the domination of older scientists and the relative immobility of personnel enable accepted theories to remain entrenched and unchallenged. The awareness of anomalies and alternative theories necessary to produce extraordinary scientific advancement is minimized in Soviet science. Even after anomalies are acknowledged and alternate theories constructed, the Soviet scientific community is slow to adopt new ideas.

> ... Soviet science is often slow to accept radical conceptual changes or take up new approaches, especially if they result from observational data from other fields. Soviet geologists, for example, have restricted plate-tectonic theory, and the new doctrine is being spread from outside their field by oceanographers. Radio astronomy has only recently achieved a status equal to optical astronomy in Soviet science policy. In psychology, the dominance of Pavlovian ideas long delayed the development of other branches of psychology, and to this day Soviet psychologists put more emphasis on neurophysiology than on neurochemistry, which stresses the molecular basis of neural activity. [Ref. 23: p. 33]

Thus, new ideas are both slow to emerge and slow to gain acceptance in Soviet science.

The effect of Russian culture, then, is to skew Soviet science toward normal and away from extraordinary research.

Thus, the Soviet system cannot maintain the tension between convergent and divergent tendencies essential to rapid scientific progress. In this, Soviet science is very similar to the Japanese scientific style described in Chapter III. Consensus, pattern recognition capability, and traditional education techniques are elements common to both cultures. And, like the Japanese, the Soviet Union must turn to foreign technology sources to prevent stagnation in the normal science phase. This dependence was cynically acknowledged by A. G. Aganbegyan, an academician and director of the Institute of Economics and Industrial Organization at Novosibirsk.

> (Once) asked whether the USSR could overtake the United States in science and economic development ... (Aganbegyan) ... replied that if that should ever happen, the Soviet Union would have to stop and let the United States get ahead again, since if (the Soviets) did not have the Americans in front of (them they) would not know which way to go. In Aganbegyan's opinion, the achievements of Soviet science are usually a function of those of the United States: as presently constituted, Russia's scientific community does not and cannot produce any fundamentally new and original results. [Ref. 23: p. 66]

Periodic reinvigoration by external sources has historically been elemental to the evolution of Russian and Soviet science. Peter the Great initiated this pattern by importing Western scientists and basing the Academy of Sciences on Western models. Catherine the Great also imported foreign expertise to modernize Russian science, as did later Tsars. The Soviet regime continued this tradition

and especially utilized German expertise in military technology in the 1920s and 1930s. This acquisition was largely in the form of industrial equipment and weapons; however, as basic scientific research became increasingly relevant to military capabilities after World War II, Soviet efforts expanded to include all aspects of foreign science and technology.

> The Soviet Union has drawn considerably on foreign science and technology, not only in the form of imported weapons (mainly in the 1930s and 1940s), but also in the form of design concepts, and more generally in basic and applied scientific research. [Ref. 18: p. 214]

Thus, reliance on foreign technology has occurred throughout Russian and Soviet history since Peter the Great. Once science and technology gained recognition as essential elements in national security, the Soviets increased efforts to acquire foreign advancements to reinvigorate their own technological base. The Soviet awareness of their dependence on foreign technology became especially evident in the 1970s when "... the thrust of official policy ... was increasingly to make foreign technology acquisition an explicit variable in R&D policy planning and world standards a specific criterion for evaluating and improving Soviet R&D performance" [Ref. 17: p. 151].

Russian culture forces Soviet science to turn to external sources for breakthroughs generated by extra-ordinary research. Like the Japanese, the Soviets are

proficient at exploiting foreign generated theories. This has been particularly evident in the incorporation of Western technology into military systems.

> Western technological developments are closely studied and are copied in those areas where they are considered of value.... This is not to be taken as proof that all advanced Soviet technology is copied from the West, but rather as evidence of Soviet preparedness to investigate and exploit technology, even if it is "not invented here." Indeed, this inquisitive attitude to technology has become one of the features of Soviet Military Doctrine. Its net result is to ensure that, although the USSR remains technologically behind the West, due to the fact that the Soviets are prepared to invest first in the military application of new technology, that technology is incorporated into battlefield systems far earlier than is often the case in the West during peacetime.

Just as the Japanese were able to rapidly excel in solid-state electronics, acquisition of foreign technology coupled with proficiency in normal science enables the Soviets to remain abreast in military technology despite their inability to generate extraordinary scientific breakthroughs.

Soviet science, however, differs from the Japanese in two significant respects. First, the Soviets lack flexibility--the characteristic which enables the Japanese to readily assimilate and modify foreign ideas. Although the Soviets actively and energetically seek foreign technology, they do so with deeply ingrained feelings of cultural xenophobia. The Soviets are keenly aware of their vulnerability should access to foreign technology be restricted. The President of the Academy of Sciences, A. P.

Aleksandrov, questioned the Soviet dependence on foreign technology by pointing out that "'it is not correct to create, through our own efforts, areas of technological backwardness by using foreign technology on an unjustifiedly broad scale'" [Ref. 20: p. 220]. This fear of vulnerability is complemented by two other Russian characteristics. One is national pride in self reliance and Russian capabilities. The other characteristic is the Russian fear that foreign ideas will disrupt consensus and foment discontent. This latter characteristic contributes to the second major difference between Soviet and Japanese science--the rapid dissemination of new ideas and reconstruction of consensus. Because of the Russian fear of losing control of the people, exposure to potentially disruptive foreign ideas is restricted to those areas where it is essential to meet the needs of national security--in other words, military research institutes. All scientists are restricted in their contact with foreign scientists, and civilian scientists also have restricted access to foreign scientific literature. Lateral communication is further confined by classification of militarily applicable scientific and technological advancements and the rigid hierarchical structure of Soviet science. In the Soviet context, this compromises the need to maintain control and the need to acquire foreign generated breakthroughs to meet national

security requirements. As a result of these differences--the lack of flexibility and restricted communications--the Soviet Union, even in military technology, does not achieve the spectacular results of the Japanese in exploiting foreign ideas. In addition, successful Soviet exploitation is largely confined to the military, and scientific development in other areas is highly uneven.

> (The) Soviet Union has demonstrated the ability to innovate, but usually in a few selected priority areas. It has not demonstrated a capacity for technological innovation along a broad front. [Ref. 17: p. 328]

Russian culture, then, significantly affects the development of Soviet science and compels the Soviet Union to acquire Western technology to meet national security needs. Cultural characteristics change only slowly even under historical pressures and Russian culture has proven especially tenacious. The effect of cultural tenacity on Soviet efforts to overcome deficiencies in divergent elements is evident in the evolution of the Academy's Siberian Department at Novosibirsk. Established in the late 1950s, the Siberian Department and the associated University of Novosibirsk were an attempt to create an intellectually dynamic center of scientific expertise. In its first decade, the project was highly successful. Young scientists were encouraged and supported, research and education were highly integrated, and organizational structures were informal to encourage interaction and communication between

personnel [Ref. 19: pp. 40-1]. With time, however, entrenched Russian characteristics reappeared.

> Khrushchev established the Siberian Department of the Academy in 1957 partly to overcome the seniority system. Many of the new institutions established at Academgorodok succeeded in bringing together young men, unfettered by their elders, who did brilliant work. Twenty years later, however, those young men are no longer so young. [Ref. 8: p. 332]

Within two decades, the informality of Academgorodok was replaced by positional stratification; gerontocracy again dominated research; and the stimulating intellectual atmosphere had dimmed [Ref. 24: pp. 153-179]. The inertia of Russian culture proved unyielding to Soviet attempts to invigorate science internally. It is therefore unlikely that the Soviet Union will develop an indigenous capability to generate and sustain the divergent elements of tension essential to rapid scientific progress. Their dependence on foreign technology will continue despite xenophobic qualms regarding their vulnerabilities. The implications for the United States are, first, that if restricted from access to foreign technology, the Soviet Union cannot compete on the scientific and technological levels, and second, that with continued access to foreign technology, the Soviet proficiency in normal science will enable them to remain abreast of, and potentially improve on, Western technological levels in deployed systems. Control of technology transfer to the Soviet Union is therefore a vital consideration in the national securities of both countries.

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